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FACTORY PRODUCTIVITY AND EFFICIENCY

III. DIRECT LABOUR PRODUCTIVITY

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This is the third article of a series of four describing the results of a detailed comparative study of productivity and efficiency in three factories in the fractional horse-power electric motor industry. The first two were:

I. Problems of Measurement. BULLETIN, *August* 1960, *and*
II. Design and Material Usage. BULLETIN, *May* 1961,

and will be referred to as I and II.

We again wish to thank the firms and managements who so generously helped us, and also the Board of Trade and the D.S.I.R., whose financial assistance made the study possible. As usual, the responsibility for the content of the articles is entirely ours.

Direct labour means the workers whose job is doing the manufacturing operations necessary to make motors. We also include any workers whose job is making good faulty work; all other workers on the factory floor (*e.g.* testers, machine setters,[1] chargehands) are in principle excluded. In these factories direct workers account for rather over half the total number of wage-earners, and rather under half the total number of employees.

The manufacture of an F.H.P. electric motor calls for a wide variety of kinds of operation. The process begins with the stamping out by heavy presses of the laminations of electrical steel from which the central electrical core of a motor is built up. Here the cost of labour is as nothing compared with the cost of equipment; the complicated dies used in the presses are very expensive. In one factory it is calculated that overhead costs in the stamping section are over ten times the direct labour cost. At the other extreme lies the operation of final motor assembly—the manual job of fitting together the various motor components with the aid of some power-driven tools. In between lie a wide range of other operations of varying capital intensities—grinding diameters on shafts, drilling holes in various components, fitting coils of wire into slots, etc.[1] In each factory all these operations have been intensively studied in order to decide how best each can be done. Not surprisingly, the factories arrived at solutions that differ in countless ways. There is no analogy here with the position found for materials—essential similarity in respect of most materials used, with major differences restricted to a few areas. In the manufacture of motors it is the similarly-performed operations that are the exception.[2] In part, this is because each factory manufactured to its own designs; but in the main it is not. In general, different techniques were adopted because the factories had different ideas as to how best to combine in a single factory the manufacture of a wide variety of motors.

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[1] In one context, for reasons we shall then explain, setters have been included in direct labour.

In each factory output in a year includes several hundred different motors; but in each also a few of these account for most of output. In such circumstances, the case for having at least two sets of manufacturing facilities—one devoted to the manufacture on a large scale of a few types of motor—is a strong one. Other things being equal a less varied output from a single manufacturing line should be made faster than a more varied one. On the one hand, it is likely that faster techniques can be used. For instance, automatic equipment can be effectively used only on fairly long runs of identical operations: or, again, operations performed on a large scale are more likely to justify the investment in developing special techniques—with or without the development of special equipment. And, on the other hand, even if there should be no differentiation of technique as between segregated facilities, the more varied output will still probably be made more slowly, as there will be some costs arising from the disturbance caused by changing over from an operation on one product to one on another. Time will be wasted while machines are re-set. The rhythm of the individual's work will be disturbed. Varying times for operations on different products will disrupt the flow of work down the line, etc. So segregation is the obvious way in which the potential economies of scale implicit in the bulk demand for a few products may be realised. But segregation may also lead to some sacrifice of the potential economies of scale implicit in the fact that one motor is rather like any other motor made to the same basic design. Most clearly, any form of segregation which led to identical components being made on different equipment simply because they were required for different motors would have obvious disadvantages. More subtly, segregation of facilities complicates the job of deciding what is to be produced where, and, if accompanied by differentiation of techniques, also the job of developing, maintaining, and utilising effectively the requisite equipment.

The case for segregation is strongest where design differences would in any case lead to differences in the content of operations on different kinds of motors. In particular, therefore, it is strongest in factory D, where motors were made to several basic designs.[1] Indeed, after April 1954, when a special-purpose design for the bulk washing-machine motor market was introduced, segregation between its manufacture and that of the other designs became virtually complete; but segregation had been widespread even before that date, when washing-machine motors were made by adapting a general-purpose design, as in the other two factories. The change in design did however lead to major changes in the forms of segregation, and these had marked effects on the times taken to make motors, even for those motors which continued to be made to unchanged designs by unchanged techniques. Indeed, the inter-temporal comparison of productivity changes within D is very instructive of the real *pros* and *cons* of segregation, and provides a useful introduction to the more complicated inter-factory comparisons, in which naturally enough the sources of difference were far more numerous.

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[1] For a brief description of motor construction, and design, *cf.* article II.

[2] For instance, in one comparison between factories of times taken to make two motors designed to serve the same use, we found that, out of the sixteen comparable groups of operations into which the manufacturing process could be sub-divided, in only three were there not major differences in the methods adopted. And in twelve of the remaining thirteen groups the differences were such that one could say unequivocally that the direct workers concerned had less work to do in one or other factory. (See pp. 243–9)

But the case for segregation was quite strong even in the other two factories, in both of which manufacture was to a single basic design. In one of them, C, there was much segregation of output. Although in some of the sections making components—usually for stock—manufacture was organised on a unitary basis, in many other sections, and on the three[2] main assembly lines, manufacture was segregated. On one assembly line, output was restricted to five washing-machine motors in bulk demand, and on the second, to a limited list (c. 80) of fairly common motors. The third—special—line, which accounted for only a seventh of total output, was used for assembling the residue, so confining the most serious consequences of product variation to a single assembly line, while still achieving in feeder sections many of the economies of scale implicit in the unity of design.

This organisation is in sharp contrast to that adopted at B, where all motors were manufactured on a single line[3], and, as far as was feasible, on the same equipment by the same techniques. The advantages of segregation were deemed not to outweigh their less obvious disadvantages. This contrast, which is the main source of the variety in techniques mentioned earlier, had pervasive influences on the way individual operations were done and on the speed with which they were done, and one of our main tasks is to clarify the *pros* and *cons* of these two organisational approaches which were in essence alternative solutions to the same manufacturing problem. This cannot be a simple task. The need for caution is brought out clearly in Table I where we compare the range of times to make different kinds of motors in each factory.

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[1] Two motors are of different basic designs if they have no important components in common. A full description of the pattern of basic designs was given in article II; details will be repeated as and when needed.

[2] These details refer to 1952–3. In 1954 a fourth assembly line organised on rather different principles had been brought into operation (see pp. 227–9).

[3] This remark refers only to the motors covered in our survey. B makes several other products on separate manufacturing lines.

TABLE I

Labour and Material Usages on Different Motors

	Percentage of different motors falling in each range:			
	At B		*At C*	
Percentage of usages on basic motor in each factory	*Material*	*Labour*	*Material*	*Labour*
Less than 95	10	—	17	—
95—105	20	42	34	16
105—125	33	34	20	20
125—150	27	23	21	31
150—175	7	1	5	20
175—200	3	—	3	11
Over 200	—	—	—	2
	100	100	100	100

Note. The percentages shown are based on samples of output in each factory, and in calculating them each different motor has been counted once, irrespective of its weight in the sample.

At B all but one in a hundred of the different motors represented in our sample of output[1] took times to make which lay in the range of 95–150 per cent of that taken for the common washing-machine motor we call the basic motor. At C, where manufacture of basic motors was largely segregated, the range was from 95 to 200 per cent, and a third of the different motors in the sample took more than 50 per cent longer to make than did the basic motor. The contrast with figures for material usages is sharp. For materials, the similarity in the ranges of motor properties was, given the decision in each to use only a single basic design, accompanied by a similarity in the ranges of material cost. But with labour this was not so; and, although there were many particular factors that go to explain this, without doubt its main source was the difference in organisational approach. The analogy is rather with comparisons of material usage covering the multiple-design factory D. And, as in that instance, nothing less than an *overall* assessment of the manifold implications of the two approaches can hope to lead to a balanced view of their relative merits.

Such overall assessments are bound to be complicated, and the sensible course is to approach them gradually. So we shall begin with a detailed and rather technical study of the ways in which, and the success with which, for a single component—the motor shaft—each factory chose to tackle the problem of combining variety in output with economy in manufacture. One major interest of this detailed study is that it was only in that limited context that we could seriously examine another aspect of economy in direct manufacturing cost—economy in the use of machinery. We shall follow this with a series of three studies of the growth of productivity within each factory over time. Two of these—those for B and for C—are fairly straightforward studies, as in both there was continuity in both design and organisation. The study of D, in which during the chosen period there was a major change in both design and organisation, provides an introduction to the problems of overall comparisons between factories with different approaches to organisation. But the inter-temporal comparisons form more than an introduction. They serve to place each factory's productivity in a particular period in its proper historical perspective, and thus to allow one to compare not only current performance, but also the rather more important matter of the potentialities for growth over time implicit in three rather different approaches to the minimisation of direct labour usage in multi-product factories.

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[1] In each factory details of output composition are confined to random samples from output records. The resultant sampling errors are however not large enough to matter, and throughout we shall write as if our knowledge of output were complete.

Labour and Machinery Productivity in Shaft Production

In this preliminary study, we make no attempt to derive ' fair ' comparative measures. In the comparison of material usage in article II, the technique of equivalence was used to provide a basis of fair comparison in which differences in the range and composition of output were taken into account. Here, by contrast, we take as a starting point the simplest possible usage measures:[1] for labour, hours worked[2] divided by the number of shafts produced; and for machinery, the value of machinery[3] used for shaft production divided by the number of shafts produced.

Designs and methods of manufacture

Usage differences in shaft production were substantial. On average, D took twice as long to make a shaft as did B or C; C used twice as much machinery per shaft produced, and D three times as much, as did B. These differences are surprisingly large: after all, the manufacture of a shaft is a straightforward engineering job, involving nothing more than a few simple machining operations on a bar of steel.

Our first objective is to measure how much of the differences in usage per shaft produced can be attributed directly to differences in the designs and methods of manufacture adopted in the three factories. For this purpose, we need to compare the labour and machinery requirements implied by the designs and methods chosen. In assessing labour requirements, we have relied chiefly on time studies prepared in the three factories. Naturally such time studies are not wholly comparable,[4] but there was a sufficient conformity for similar operations on similar machinery to justify their use in deriving

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[1] In this section, it will be convenient to work with measures of usage—input per unit of output—rather than the productivity measures—output per unit of input—which are their reciprocals. Relatively high usage means relatively low productivity, and *vice-versa.*

[2] The hours worked by operators, machine setters, and setter-operators. Machine setters are excluded from ' direct labour ' in other sections of this article; but they have to be included here because the setting work done by setter-operators at one factory was done by setters at another.

[3] At estimated 1954 replacement cost.

[4] Times normally include various ' allowances ' in addition to basic operating times. Where allowance practices differ, adjustments can be made to secure a greater measure of uniformity.

TABLE II

Labour and Machinery Requirements for the Basic Shafts
(Requirements at B=100)

Group of operations	C Labour[1]	C Machinery[2]	D Labour[1]	D Machinery[2]
Turning	46	250	46	250
Grinding	133	133	100	100
Other operations	144	116	167	48
All shaft production operations ...	92	162	88	129

[1] Relative times required to perform the operations called for by the designs, using the methods adopted at each factory. Required times are based on a synthesis of time studies.

[2] Relatives based on the product of time required for each operation and the estimated 1954 replacement cost of the machinery used.

estimates of required operation times on a standardised basis.[1] Machinery requirements have been estimated by multiplying the required operation time on each machine by the estimated 1954 replacement cost of that machine. Thus two operations have the same machinery requirements if one takes half as long as the other on machinery twice as costly.

Table II shows a comparison of requirements in 1955 for the shafts fitted into the commonest washing-machine (basic) motor at each factory. The differences in requirements for the turning and grinding operations were entirely due to different methods of production: the designs called for very similar work. C and D used expensive multi-tool ' automatic ' lathes which performed all the required turning operations[2] simultaneously, whereas B chose a slower method, involving several successive operations on simple and far cheaper lathes. All the factories used similar machines for the grinding operations.[3] B and D had lower requirements for labour and for machinery because they used special tools which enabled two diameters to be ground simultaneously, while C ground each diameter separately. For the other operations,[4] requirements differed because different operations were called for by the designs of the shafts.

We do not have the information—or the skill—to enable us to judge whether this method or that design is ' better ' than another. For example, machinery requirements relate only to the machines used, and do not take into account the associated costs of tooling, maintenance, and so forth. Or again, it may well be—particularly for the grinding and ' other ' operations —that there are considerations of reliability to be considered in the choice

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[1] Our procedure was analogous to the familiar time-study technique of preparing a ' synthetic ' study for a complex set of operations. On the basis of the studies prepared in each factory, a standard time was estimated for each operation by each method. By an appropriate combination of standard times, the time required by any given set of operations performed by given methods can be derived.

[2] In the turning operations, metal was cut away from the steel bar to form the various diameters called for by the design.

[3] Those diameters which had to be extremely accurate were, after turning, ground down to precise specifications.

[4] The most important ' other ' operations were those which made provision for fixing the rotor and the centrifugal mechanism to the shaft.

TABLE III

Labour and Machinery Requirements per shaft: Operations for Output as a Whole
(Requirements for basic shaft at B=100)

	B		*C*		*D*					
					Design D1		*Other designs*		*All designs*	
	L	*M*	*L*	*M*	*L*	*M*	*L*	*M*	*L*	*M*
Basic shafts	100	100	92	162	88	129	(88)	(129)	(88)	(129)
Add for:										
Additional operations	+1	+1	+2	+2	—	—	+ 3	+ 3	+ 2	+ 2
Different basic designs	—	—	—	—	—	—	+46[1]	+65[1]	+21	+29
Different methods ...	+1	+2	+4	−6	—	—	+36[1]	−29[1]	+17	−13
Totals	102	103	98	158	88	129	173	168	128	147

Note —*L*=Labour; *M*=Machinery

[1] Since all shafts of designs other D1 than were produced by different methods, the split of additional requirements between methods and design must be arbitrary. The additions for methods represent the additional labour and machinery which would have been required by the use of slower methods if shafts of designs other than D1 had called for the same number of turned and ground diameters as shafts of design D1.

of method or design. A ' faster ' method may have little to commend it if it increases the proportion of faulty work. What is interesting is that for no group of operations did all three factories make the same decisions, even though the technical problems were similar and the alternative solutions were well-known.

Table III extends the analysis of labour and machinery requirements per shaft to output as a whole. Even at C, where the variety of shaft output was least, 75 different shafts were made in a 30-week period; at D, no fewer than 318 different shafts were produced. All motors produced at B and C conformed to their single basic designs, which were adapted to cater for a wide variety of uses. Some of the adaptations affected the shaft—for example, more powerful motors with a larger electrical core needed longer shafts. But by ingenious standardisation, which permitted the same shaft to be used in different motors, both these factories could cover their standard ranges of output with a couple of dozen different shafts. Furthermore, efforts were made, particularly at B, to standardise production by ensuring that as many operations as possible were identical on different shafts.[1] Variations to cater for the standard range accounted for under a third of the number of different shafts produced: the remainder were special adaptations to meet the needs of individual customers. Such adaptations were almost entirely concentrated on the shaft extension, the portion of the shaft which protrudes from the motor to provide the drive for the customer's equipment. In general, the adaptations which these two factories were prepared to produce for special orders were fairly straightforward, often involving nothing more than an extension of a different length. Because all shafts produced had so much in common with the basic shafts, and because the few really complicated shafts were produced in relatively small quantities, the additional requirements for output as a whole attributable to more or more complicated operations were slight.

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[1] Thus at B, the operations required at one end of the shaft were identical for most motors produced.

At D, however, several basic designs were produced[1], and the higher labour and machinery requirements for the operations called for by designs other than D1 (the special purpose design for washing-machine motors to which the basic motor belonged) made an important contribution to raising requirements on the ' average ' shaft. Within each of these other general-purpose basic designs, shafts were less standardised than at B or C: a greater number of different shafts was needed to cover a given range of motor characteristics, there was less similarity in the operations required to produce different shafts, and a far greater number of different shafts were produced to special order. Yet this lesser standardisation within designs was unimportant in raising operation requirements: it was the differing requirements of the various designs that was crucial. Other designs were far more complicated than D1, and indeed more complicated than the designs at B or C; on any method of production labour and machinery requirements would have been higher. Some of D's designs catered for uses which could not be matched by B or C, and it might be argued that the additional complexity of design was a necessary consequence of the decision to cater for a wider range of uses. This argument can only have a limited validity; for the D2 design which covered a similar range of uses to the designs at B and C was itself more complicated. Before 1954, adaptations of the D2 design had been produced for uses subsequently catered for by design D1. The introduction of the streamlined special-purpose design D1 had permitted substantial savings in the labour and machinery requirements for shaft production at this factory, but on balance there were no such savings in relation to corresponding shafts of the general-purpose designs at B and C.[2] There is a clear analogy with the analysis of material usage in article II. D1 used less material than D2, but no less than C's general-purpose design, so that D's usage was greater than C's because the relatively uneconomical design D2 was still produced for many of the uses catered for by C's general-purpose design. We suggested that some of the D1 material economies might have been achieved on the general-purpose designs—and certainly the design of shafts for the general-purpose designs at B and C was as simplified as that of shafts for D1 motors. Be that as it may, it is clear that D's requirements for output as a whole were strongly influenced by the distribution of output between designs; and at this period, nearly half of its output contained shafts of the more complicated general-purpose designs.

Finally, requirements for output as a whole will differ from those for the basic shafts because the methods of production used for the latter were not used for all shafts produced. Basic shafts were in bulk production at all factories, and methods adopted to speed the production of shafts produced on a large scale may be inappropriate for shafts produced on a small scale.

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[1] These designs were described in article II.

[2] Though materials were saved by using a thinner bar steel for the shaft.

TABLE IV

Distribution of Shaft Output for a 30-week period in 1955

Scale of production of particular shafts	*Number of different shafts*			*Percentage of output*		
	B	*C*	*D*[1]	*B*	*C*	*D*[1]
More than 10,000	4	4	2 (2)	47	78	39 (39)
1,000—9,999	15	11	17 (3)	40	18	46 (13)
100— 999	48	15	50 (1)	11	3	12 (1)
10— 99	46	28	72 (—)	1	1	2 (—)
Less than 10	9	17	177 (—)	—	—	— (—)
Totals	122	75	318 (6)	100	100	100 (53)
Total output, B=100	100	154	98 (52)			

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[1] Bracketed figures relate to shafts of design D1 only; unbracketed figures to shafts of all designs.

One such method was the technique for the simultaneous grinding of two diameters used at B and D. The necessary tools have to be made for specific combinations of the two diameters, and where shafts call for unusual combinations of diameters, the production of an appropriate tool may not be justified. Thus B used simultaneous grinding for most of its shaft output, and the very small addition to requirements for output as a whole was attributable to the use of individual grinding for those shafts which called for unusual combinations of diameters.

C and D used automatic lathes for their basic shafts; but because an automatic lathe takes a relatively long time to re-set (*i.e.* to alter the setting of the tools from that appropriate to the production of one shaft to that appropriate to the production of a different shaft), it would be quite uneconomic to use it for small batches of shafts. One view is that an automatic lathe is only worth while for batches of at least 1,000 identical shafts, and that even larger batches are desirable. This rule of thumb presupposes a considerable similarity of turning operations between successive shafts produced: re-setting time rises sharply as the number of dimensions which have to be changed increases, so that the greater the differences between successive shafts the larger the desirable size of batch. It follows that factories producing a varied output, and using an automatic lathe for some of their shafts, must provide an alternative method of manufacture for shafts produced on a small scale. The alternative method provided at C and D was essentially the same as that used on the basic shaft at B: a set of simple and easily re-set lathes to perform the required operations successively. C and D had to use two methods of turning, whereas B used the same method for all its shafts.

It is clear from the information given in Table IV that C's output was in some ways more suited to the extensive use of automatic turning than was D's. Its total output was much higher, and much more concentrated on a few shafts in bulk production. Furthermore, C's shafts all conformed to a single basic design: the time which would have been required to re-set from

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TABLE V

Shafts Turned by Different Methods

Nine commonest shafts ranked by numbers produced	*C*		*D*	
	Automatic	*Slower*	*Automatic*	*Slower*
1	X		X	
2	X		X	
3	X			X
4	X			X
5	X	X	X	
6	X	X	X	
7	X	X	X	
8		X		X
9	X	X		X

Note. X indicates that some shafts were turned by the method specified during the period.

a D1 shaft to a D2 shaft was substantially higher, because every dimension had to be changed, than that required to re-set from any of C's bulk production shafts to any other. In fact, C used automatic turning for over 85 per cent of its total shaft output, and the changes in requirements attributable to the use of slower turning methods (see Table III) on the remainder of output were small. D used automatic turning (and simultaneous grinding) only for D1 shafts. Nearly half its output was therefore produced by slower methods, and requirements per shaft in total output were for this reason very different from its requirements for the basic shaft. It does not, of course, follow that the use of automatic turning at D was inappropriate. An automatic lathe has a high potential weekly output, and the single automatic lathe installed at D was fully occupied during normal working hours in the production of D1 shafts. On the output of this period, the single automatic lathe could effectively be used for D1 shafts. Had a second automatic lathe been installed, it would have been grossly under-utilised in producing a smaller and much more mixed output. With such indivisibilities present, it is clear that the proportion of output which could be turned on an automatic lathe was sensitive to the level and distribution of output. Yet if it was advantageous to use automatic turning for bulk-production shafts—and both C and D considered that it was—then it was advantageous for D to use this method even though nearly a half of its output had to be turned by a slower method.

In other circumstances, however, it could be more difficult to maintain effective utilisation at D than at C. Say, for instance, that there was a fall in the demand for motors containing D1 shafts; it was in fact a demand subject to considerable fluctuations. D would be faced with the alternative of under-utilising the lathe by producing fewer shafts on it, or of using it to produce a mixture of D1 and D2 shafts which would involve under-utilisation because of the substantially greater re-setting time needed to change over to a different design. Table V gives an impression of loss of flexibility when differentiation of methods is associated with differentiation of design. At D some shafts in bulk production were turned by slower methods, solely because they were not of the D1 design; and no shaft of D1 design was turned by slower methods. At C, by contrast, there were no sharp dividing lines, and both methods were used for some shafts. If there were a fall in the demand for the most popular motors, more of the shafts for less popular motors could be turned automatically; and if there were a rise, turning by slower methods could supplement the output from the automatic lathes.

The level and distribution of B's output was as favourable to automatic turning as was D's; and because of the unity of its design it could have used this method more flexibly. It has already been noted that B was a factory which was unwilling to differentiate methods of manufacture; and it is a consequence of this approach that economies achievable only on a part of output will not be secured. But there is a further reason for B's decision not to use automatic turning. Both C and D turned on their automatic lathes shafts which were, on average, produced at rates of 200 and even 100 per week. Such rates were compatible with sufficiently large batches for automatic turning only because the factories were willing to produce for stock. In general, since the larger the batches the lower the proportion of time spent re-setting, the greater the willingness to hold stocks the more effectively the lathe can be utilised. At B there was a definite unwillingness to hold stocks; and its choice of methods was influenced by the way in which it chose to organise its production.

Yet despite the fact that B did not adopt a method which yielded substantial savings in labour time at the other factories, its labour requirements per shaft were only slightly higher than C's. What it lost on its labour-intensive method for the turning operation it regained on a faster method of grinding and on a design which called for less time-consuming ' other ' operations. These gains did not involve any significant differentiation of techniques between different shafts produced: the same machinery was used for the production of all shafts. C's use of automatic turning involved greater machinery requirements, but it also needed more machinery than B for the remaining groups of operations. In all, its machinery requirements per shaft produced were more than 50 per cent higher than B's, a difference which some way towards accounting for its much higher machinery usage per shaft. The requirements for output as a whole at D also go some way towards accounting for its higher labour and machinery usages. There, requirements for the basic shaft were a very poor guide to requirements for output as a whole, since differences in design and methods were such that nearly half the shafts in its output took twice as long to make, and needed much more machinery, than did its basic shaft. Nevertheless there remain substantial differences in usages of labour and machinery per shaft which cannot be explained in terms of differing requirements as measured, and which are attributable to differences in what we shall call the ' utilisation ' of labour and machinery.

The utilisation of labour and machinery

The 'utilisation' of labour or machinery is defined to be the ratio between requirements and usage. The usage of labour consists of the time spent by workers employed on the operations of shaft production *plus* the time spent by workers employed on the re-setting of shaft production machinery. Since labour requirements relate only to requirements for the operations of shaft production, a measure of 'utilisation' of labour is *not* a direct measure of the rate of work in the sense of a ratio between time spent on operations and the time required for operations. Similarly, the actual usage of machinery is defined in terms of the value of machinery (at 1954 replacement cost) used for shaft production, and its 'utilisation' will be affected by any time not spent on the required operations—including the time during which machinery was being re-set.

The relative requirements of labour and machinery for the operations of shaft production can be estimated with fair accuracy, and the causes of differences between factories identified. It is not possible, however, to be so specific about the causes of differences in the 'utilisation' of labour and machinery. In Table VI, D shows up as a factory with a relatively low utilisation of both labour and machinery. It will be noted that its low utilisation was associated with relatively high requirements—an association which also held for machinery at C. Such an association is plausible enough: lower requirements and higher utilisation both contribute to lower usage per shaft produced, and systematic efforts to secure lower usage—higher productivity—could be expected to show up in both measures. Yet the designs and methods of production which reduce requirements do not of themselves raise utilisation, or even necessarily make it easier to raise utilisation. The association indicates that there are several facets to the achievement of lower usages per shaft produced, but it gives no guidance on why utilisation differed. The apparent association at D between lower utilisations and the employment of labour with a relatively low cost per hour worked seems more promising. In so far as labour with a higher cost per hour is 'better'—for example, better-trained—labour, it is likely that a higher utilisation can more easily be achieved. But if higher cost labour is used, it becomes more crucial to solve the production problem in such a way that utilisation is higher, since otherwise the use of higher cost labour will merely raise the cost of producing motors. Indeed to some extent higher hourly labour costs were a consequence of higher utilisation: the incentive schemes of labour payment used at B and at C would raise labour cost per hour as utilisation improved. Relationships between pay and productivity are complicated, and cannot usefully be discussed in a study confined to a single component.[1] For the present we note, as an item of background information, that there were major differences in the hourly cost of labour employed in these factories, and move on to consider how the factories solved the production problems they faced.

Clearly one important element in that problem is the variety of output to

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[1] They will be considered in a later section of this article (see pp. 260–270)

TABLE VI

Productivities and Costs in Shaft Production

(*Index numbers, B=100*)

	B	C	D	D	
			All designs	D1	Other designs at D
Output					
Level of output	100	154	98	52	46
Actual number of different shafts produced	*122*	*75*	*318*	*6*	*312*
Labour					
Labour usage (hours worked per shaft)[1]...	100	95	192	86	313
Labour requirements per shaft[2]	100	96	125	86	170
Labour utilisation per shaft[3]	100	101	65	100	54
Labour cost per hour worked	*100*	*90*	*54*	*55*	*53*
Labour cost per shaft produced ...	*100*	*85*	*104*	*47*	*166*
Machinery					
Machinery usage (value of machinery per shaft)[4]	100	212	293	186	415
Machinery requirements per shaft[2] ...	100	153	143	125	163
Machinery utilisation per shaft ...	100	72	49	67	39
Hours per week for which labour available to work machinery[5]	*100*	*115*	*74*	*74*	*74*
Machinery utilisation per shaft, per hour worked	*100*	*62*	*66*	*91*	*53*
Labour and Machinery					
Labour and depreciation cost per shaft produced[6]	100	102	131	65	206

[1] Hours worked by operatives, setters, and setter-operators employed on shaft production.

[2] From Table III, adjusted to B=100.

[3] Labour requirements divided by hours worked.

[4] At estimated 1954 replacement cost.

[5] Derived from a rough calculation designed to show the expected effects on machinery utilisation of shift and overtime working.

[6] Assuming uniform depreciation at 10 per cent of 1954 replacement cost per annum.

be produced. The most direct way in which greater variety will lower the 'utilisation'—given the way in which we have defined this term—of both labour and machinery is by raising the setting work that has to be done. To produce a different shaft, some machinery will have to be reset to work to different dimensions: that machinery will be idle whilst it is being reset, and labour time will be spent on the re-setting. In addition, there are almost bound to be change-over delays, as operators wait for machines to work on or as machines wait for operators. And, finally, it must take time, no matter how adaptable the worker, to get into the swing of a different operation. It is a major task of factory organisation to limit these consequences of producing a varied output.

Within D, the utilisation of both labour and machinery was much higher on its output of D1 shafts than on its varied output of shafts of other designs. The six different D1 shafts contributed more than half total output. More than 300 different shafts of other designs were produced over a 30-week period: none was produced on a really large scale, and very many were produced in ones or twos (see Table IV). For the latter, the time spent on the necessary operations may be almost negligible in relation to setting time; whereas for shafts produced on a larger scale setting time may be almost negligible in relation to operation time. In addition, it seems likely that at that time, D's energies were concentrated on raising utilisation on D1 shafts, to the comparative neglect of the far more difficult problems of improving utilisation on shafts of other designs. Even so, it is striking that labour usage per shaft of other designs was nearly four times that on D1 shafts: and only a half of that difference can be accounted for by differences in the operations that had to be done.

The output of the other designs at D was exceptionally varied. Neither B nor C was called upon to produce so many different shafts, and each produced very few shafts in ones and twos. Nevertheless, if further information on utilisation were available, no doubt major differences would be found at these factories between utilisations on shafts in bulk production and shafts produced on a small scale. But it should be noted there were three quite different outputs on which labour utilisation was very similar; total output at B and C, and the output of D1 shafts at D. D's output comprised only six different shafts, B's 122, and C's much larger output 75.

Before the implications of this similarity in labour utilisations can be understood, some features of the organisational background to shaft production must be noted. We may begin by taking a closer look at machinery utilisation. One way of improving the utilisation of machinery is to work shifts, and both B and C—but not D—were working shifts on shaft production in this period. C worked double-day shifts on bulk-production shafts, and a major advantage was that the most expensive machines in shaft production—the automatic lathes—were used more intensively than was possible at D. B's night shift, by contrast, was primarily intended to clear the decks for the much larger day shift. It produced the shafts which were for some reason awkward to produce, or which were ordered in small quantities, and which would have disrupted the flow of work during the day. Because B's choice of methods was such that the same machinery was used for all shafts, the machinery used for day-time production could be used for the relatively complicated output of the night shift. Although no reliable separate figures are available, the utilisation of both labour and machinery was definitely much lower on the night than on the day shift, as indeed is only to be expected given the sort of output produced. The positive contributions of the night shift were the easing of the flow of work during the day, and the production of the more mixed portion output without additional machinery. At C and D the more mixed portion of output did require additional machinery—both because different methods were used, and because it was produced at the same time as the less mixed portion.

When the machinery utilisation figures are adjusted by a factor that reflects the hours per week for which labour was available to work the machinery, the utilisation of machinery per available labour hour appears to be about 30–40 per cent lower at both C and D than at B. Before adjustment, C's utilisation was similar to that on D1 shafts: double-shift working enabled C to achieve as high a utilisation on the whole of its output as D achieved on the most straightforward portion of its output. But per available labour hour, C's utilisation was no better than D's on the whole of its —very complicated—output: and D's utilisation on D1 shafts approached B's.

To some extent, a lower utilisation of machinery per available labour hour will be associated with a lower utilisation of labour. If operations take longer than the required time, and if the time spent on re-setting is high, machinery will be in operation for longer than the required time, and much machinery will be idle whilst being re-set. It will be noticed that at B and D (both for D1 shafts and shafts of other designs), labour utilisation and the utilisation of machinery per available labour hour were very similar: C, on the other hand, had a high labour utilisation in relation to its machinery utilisation. The inference is that there was some form of excess capacity at C: and this does not conflict with our impression from observation that the provision of machinery was relatively ample at that factory. We do not mean to imply that there was a ' wasteful ' use of machinery at C. In several ways, an ample provision of machinery may make a positive contribution to raising labour utilisation. Thus, if a ' spare ' machine can be set-up for the next batch so that an operative can move straight on to it when he has finished his batch on another machine, change-over delays for labour can be minimised. Or again, reserve capacity which can be switched in if a breakdown occurs on another machine is obviously valuable—even though the reserve capacity will in any formal calculation appear to be grossly underutilised.[1] With machinery of the sort used for shaft production, it is generally cheaper to under-utilise machinery than to under-utilise labour. It was our impression that D, for example, was working on very narrow margins at this period, and that labour utilisation was adversely affected by machine breakdowns and the like.

A further element in the organisational background to labour—and indeed machinery—utilisation is the way in which output was planned. So far, we have used the number of different shafts produced over a period as an indicator of the variety of output to be produced. Certainly the production of a different shaft entails re-setting—but it is production planning which determines how often equipment has to be reset to produce the same shaft during a period. Thus the production of, say, 3,000 identical shafts over a period of 30 weeks could involve 3 batches of 1,000 shafts or 30 weekly batches of 100 shafts. The planning of output in such a way as to permit the production of larger batches can materially reduce the number of resettings necessary to produce a given number of different shafts, and so contribute to higher labour utilisation. On the other hand, the larger the batch in relation to the average weekly output, the greater must be the willingness to hold stocks. Planning procedures in these three factories differed in many ways, and this makes a comparative assessment difficult. There is, however, no doubt that B was less willing to hold stocks than either C or D; and for this reason any equally varied output over a period would tend to be produced in smaller batches at B. The different attitude to production planning at B was mentioned as one of the reasons for B's decision not to use an automatic lathe—such a lathe can be used effectively only if large batches are planned.[1]

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[1] The holding of spare or reserve capacity will also be influenced by the space available on the factory floor. Certainly part of the higher apparent machinery utilisation at B could be attributed to an extreme shortage of manufacturing space: there was no room for underutilised machinery. C, particularly, had more space available, and older machinery could be retained in a stand-by role without any great inconvenience or expense.

When the numbers of instructions to produce different shafts issued by planning departments—it is these instructions which authorise and initiate production on the factory floor—are divided into the total output produced, it appears that the average size of batch authorised was highest for D1, lower at C, lower still at B, and lowest for D's other designs.[2] This is the order which would be expected from the level and distribution of outputs, irrespective of any differences in planning procedures. But the difference between average batch sizes at C and B was substantially greater—the former's average batch size was more than 2½ times larger—than would be expected, and a more detailed investigation shows that a major cause was the much bigger batches authorised for bulk production shafts at C.

Consider now the similarity in labour utilisation on C's total output, and on the output of D1 shafts. Certainly the average size of batch was much lower at C. But a high proportion of C's output consisted of bulk-production shafts: five different shafts accounted for over 80 per cent of its output, and the output of its commonest shaft far exceeded that of all D1 shafts together. For this preponderant portion of output, C had a simpler production problem than D; it exploited potential labour and machinery utilisation economies by planning really large batches, and raised machinery utilisation through double-shift working. C, like D, was prepared to differentiate its methods in order to lower labour requirements on its bulk-production shafts, and the evidence suggests that its efforts to raise labour utilisation were also concentrated on the production of these shafts. C's average labour utilisation was probably pulled down by a lower utilisation on the more mixed portion of output, though it is highly unlikely that its utilisation on that output could have been as low as D's on its other designs. Far fewer different shafts were produced, there was a greater standardisation of design, and there was a more ample supply of machinery to assist the flow of work. The tentative conclusion is therefore that C's labour utilisation was higher than D's, both

[1] At one factory, the average time taken to re-set an automatic lathe was well over three hours: even for a batch of 2,000 shafts, setting time would amount to some 7 per cent of operation time.

[2] The average size of batch authorised was not necessarily the average size of batch produced, since a further batching may take place on the factory floor. Batching outside the planning departments was probably more important at C than at the other factories.

on relatively unmixed and on relatively mixed output. On both portions of output, C had the simpler production problem—and so much of its total output was relatively unvaried that its average utilisation approached D's utilisation on D1 output. In effect, the approach of concentrating on raising utilisation on bulk outputs was peculiarly suited to C's structure of output.

B's whole approach was different. Far from concentrating on bulk outputs, it seemed almost to ignore their existence. In its choice of methods, it had deliberately chosen techniques which would be applicable, with a minimum of modification, to the production of any shaft—at the cost of not adopting a technique suitable only for bulk-production shafts. Partly because C and D used different production techniques for bulk production shafts, these shafts were made on entirely segregated manufacturing facilities: there was no such segregation at B. Nor did B, in its planning of production, authorise batches for bulk-production shafts of a size comparable with those authorised at D, let alone C. In fact, B made no concessions to 'bulk' outputs, and with all shafts treated on a par, the problem of producing a varied output was squarely faced. The most varied part was, it is true, taken off by the night shift; but the average size of batch produced on the day shift remained far smaller than the average size of batch at C. Nor was the problem of securing high labour utilisation eased by provision of ample machinery: but whereas at D there were signs that a tight machinery position was adversely affecting labour utilisation, there were no such signs at B. Indeed, the main emphasis at B seems to have been on speeding the flow of a varied output through the available machinery. To the extent that this policy was successful, high utilisation of both labour and machinery went hand in hand: the provision of additional machinery would tend to reduce the effectiveness of pressures for higher utilisation. Our utilisation figures indicate a considerable measure of success: labour utilisation on the day shift must have been very high, since the inevitably low utilisation on the night shift did not reduce average utilisation below that achieved at C or on D1. The production problem was eased by a greater standardisation of design between different shafts than in either of the other factories, and the standardisation of methods also helped. If 'slow' methods are used only for a very varied output, a low utilisation on those methods may be regarded as inevitable. But if, as at B, they are used for all output, the potentialities for higher throughput can be exploited. And it is a fact that the potentialities of the slow methods were greater than those of the fast methods. The throughput of an automatic lathe, for example, can be increased only by cutting re-setting times, or by reducing the lathe's cycle time. The former is largely a matter for planning, the latter for the engineering department: the operator of the lathe himself can do little to speed the throughput. But with simpler and slower lathes, the throughput is much less closely determined by machine cycle times: it can be substantially increased by the skill and dexterity of the operator. So B's approach was most likely to be successful if the labour employed was relatively skilled and adaptable—pressure on individuals can succeed only if they are of the kind to respond to such pressure. At B, evidently they did; but the figures for the hourly cost of labour (see Table VI) suggest that such labour may be relatively expensive. As between C and D1, it was not necessary to suggest that the rate of work by operatives was higher at one of the factories: but, as between B and both C and D1, the evidence leaves no doubt that a higher rate of work at B was a necessary part of the explanation of similar labour utilisation.

There are, of course, potential disadvantages both in a concentration on raising utilisation on bulk-output shafts, and in a concentration on raising utilisation over the whole range of a varied output. The danger of the former approach is that a comparative neglect of the more varied part of output may substantially lower average utilisation. The danger of the latter approach is that the possibilities of lowering usages on bulk-production shafts—particularly through differentiation of technique—may be neglected. To some extent, therefore, the assessment of the merits of either approach must depend on the sort of output which was produced. When considering B's approach, for example, it is all too easy to forget that six shafts contributed over 60 per cent of output: there will be disadvantages, as well as advantages, of treating these shafts as if they were in no way to be differentiated from shafts whose contribution to total output was negligible. Had B's output been as concentrated as C's, the case for differential treatment would have been still stronger. On the other hand, it does not follow that B's approach would have been suited to a much more varied output, such as was found at D. As it was, B used a night shift to reduce its day-time variety to manageable proportions: faced with the variety of output produced at D, its high-pressure system would probably have burst at every seam.

We do not propose to dwell on the size of the differences in usages or costs in shaft production. Table VI shows that B and C had similar labour usages per shaft produced, and therefore similar labour productivities. B had a much lower usage of machinery—higher machinery productivity—than C; but on a comparison of labour *plus* depreciation costs, the two factories were again roughly equal. B's lower depreciation costs were largely offset by the higher hourly cost of the labour it employed. D emerged as a factory with higher usages and therefore lower productivities; and higher labour *plus* depreciation costs per shaft produced. But it is of interest to note that D nevertheless produced its bulk-output shafts at a cost which the other factories could not approach for any shaft.

Such comparisons are not fair comparisons; for they take no account of differences in the scale, range or composition of outputs. In any case, levels of productivities or costs for a single not very important component give no reliable guide to comparative levels on all operations. But our purpose in this introductory study has not been to reach general conclusions about the comparative performance of these factories, but rather to elucidate the varied and complicated ways in which the kind of performance achieved was linked with the work that had to be done and with the way in which the work was organised. Even for a single component, elucidation was far from easy or complete; and not the least important impression to be carried forward to the general study is that of the variety of factors which were found to be relevant to an appreciation of the relative merits of differing approaches to the problems that arise in manufacturing a varied output of a single component.

THE SOURCES OF RISING PRODUCTIVITY

Our period of comparison is brief—a mere 2½ years, divided up for convenience into five half-yearly periods.[1] A comparison over a longer period would in many ways be more interesting; but since with the passage of time records have to be disposed of in order to make room for new ones, it could not be done with the thoroughness possible over the short period. Our actual period was the 2½ years from January 1952 to June 1954, although we did collect some figures relating to 1955 to cover particular aspects in which actual performance in 1954 was definitely atypical.

TABLE VII

Simple Measures of Changes in Direct Labour Productivity

(1952 (1)=100)

Period	*Numbers of motors made*			*Total hours worked*			*Motors made per hour*		
	B	*C*	*D*	*B*	*C*	*D*	*B*	*C*	*D*
1952 (1)	100	100	100	100	100	100	100	100	100
1952 (2)[1]	26	85	51	not available			not available		
1953 (1)	34	86	48	32	84	45	107	103	106
1953 (2)	44	108	74	42	90	60	106	120	123
1954 (1)	67	139	88	59	121	64	114	115	139

Note. In this table, D's figures relate to the output of induction motors as a whole, and not just to the range that is comparable in uses served with those made in the other two.

[1] In 1952 (2) hours fell much more sharply than final output as drastic cuts were made in stocks of components and other work-in-progress. Figures of motors made per hour would be completely misleading.

The period studied was one from boom to slump and back to near-boom. In January 1952 each factory was working flat out; but by June demand had fallen away sharply, and the next two half-years were periods of low demand. Then, following budget concessions, demand picked up, and by 1954 there was again some pressure on manufacturing facilities, although output was to rise still further in 1955. In two of the factories, B and D, the slump was very severe, output falling to under a third and under a half of its earlier level respectively, and even by 1954 their recoveries were far from complete. In C the slump was mild, partly because a policy of stockpiling motors insulated the factory from the full force of the fall in demand, and partly because over time C was capturing a larger share of the market for the induction motors we are studying.[2] This violent cyclical fluctuation in output is a post-war characteristic of the F.H.P. motor industry, as indeed of most industries manufacturing consumer durables or their components, and is one of the main headaches of factory management.

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[1] 1952 (1) will be used to mean the first six months of 1952, etc.

[2] All the factories manufactured some other products, and changes for these motors alone give a wrong picture of the change in scale of factory activity. In B the growth in the output of other products more than offset the decline for these motors, and it was only in D that there was a real fall in the scale of factory activity over the whole period.

Total hours worked by direct labour followed the same cyclical pattern. In the slump there was a sharp reduction, leading in all factories to declarations of redundancy, as well as a cessation of overtime and recruiting. In C, in addition, shift-working was suspended during the slump, to be re-introduced gradually as demand picked up: but even in 1954 some departments which had worked shifts in 1952 had not reverted to shift-working.

Much the simplest measure of productivity is the ratio of the number of motors made to total hours of work. Owing to the violence of changes in work-in-progress this measure would be useless for 1952(2),[1] and this period is therefore omitted. In all the other periods productivity so measured was higher than in 1952(1). Over the whole period B and C achieved a rather similar advance of 15 per cent; D, starting from a very much lower level, achieved a much sharper increase of nearly 40 per cent. The timing of the advance in different factories was however dissimilar. In all three there was some gain between the boom of 1952(1) and the bottom of the slump in 1953(1), even surprisingly enough in B and D where the decline in output was so sharp; but thereafter there was no uniform pattern.

These simple measures ignore two factors of crucial importance—the composition of the hours worked and the composition of output. Both changed substantially, and in such ways as could have had pronounced effects on the average times taken to make a motor. But it is not easy to measure the likely effects of either type of change. As regards input there was in no factory any major change in the grades of labour employed. Operations which in 1952 were done by women continued to be done by women throughout, and only in C did a difficulty in recruiting boys force a change in the grade of labour used to do certain operations. But there is no doubt that the average ' quality ' of labour did vary sharply from period to period. The redundancy declarations of 1952 naturally fell most heavily on the most recently-recruited and least experienced workers, so that in the slump the average quality of the labour force was higher than in 1952. Then, as recruitment was resumed, there were sharp falls in average quality, as the proportions of trainees and green labour rose; and many of the short-run variations in productivity can be explained in terms of this single factor of degree of experience. But only in B, where there existed separate records referring to the productivities of trainees, of inexperienced and of fully experienced workers, can its effects be shown directly.[2]

We can, however, attempt to measure the likely effects of changes in the composition of output, using the technique described in article I. The results are shown in Table VIII.

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[1] We did make an attempt to adjust for such changes, but the attempt was worthless.

[2] See pp. 220–1.

TABLE VIII

Adjusted Measures of Direct Labour Productivity

(1952 (1) = 100)

Period	*Average hours required per motor*			*Number of motors made per hour*			*Productivity adjusted for changes in output composition*		
	B	*C*	*D*	*B*	*C*	*D*	*B*	*C*	*D*
1952 (1) ...	100	100	100	100	100	100	100	100	100
1952 (2) ...	99½–100½	105–105½	114–116	not available			not available		
1953 (1) ...	99	100½–101	106–107	107	103	106	106	103–104	112–113
1953 (2) ...	99½	97–97½	93–94	106	120	123	106	116–117	114–115
1954 (1) ...	99–99½	98–98½	89–90	114	115	139	113	113–114	124–125

Note. The system by which the figures for ' hours required per motor ' are calculated was fully described and discussed in article I. Briefly, the comparative productivity of two factories A and B—or of the same factory in two periods, A and B,—in manufacturing an output of the composition of factory or period A, is measured by the formula:—

$$\frac{\sum_{r} n_r^{(A)} l_r^{(B)} \Big/ \sum_{r} n_r^{(A)}}{\sum_{r} n_r^{(B)} l_r^{(B)} \Big/ \sum_{r} n_r^{(B)}} \div \frac{L^{(A)} \Big/ \sum_{r} n_r^{(A)}}{L^{(B)} \Big/ \sum_{r} n_r^{(B)}},$$

where n_r and l_r refer to the numbers made of and time taken to make individual motors in each factory or period, and L to the total usage of direct labour. Use of the times $l_r^{(A)}$ in place of the $l_r^{(B)}$ gives a measure of comparative productivity in manufacturing an output of the composition of factory or period B. Where designs differ between factories, or have been altered over time within a factory, the n_r's and l_r's refer to equivalent motors, *i.e.* to motors differing in design but not in intended use.

In the table, the first columns ' average hours required per motor ' are just the first terms of the expression given above. In computing these we have used sets of l_r's derived from two periods. In B and in C these were 1952 and 1954, and in D 1952 and late 1953. Comment about the effects at D of using l_r's from a period after the change in design in April 1954 will be given later (see p. 236).

At B the implications of our measures is straightforward—compositional changes may be ignored. They were anyhow comparatively minor; but the absence of effect, even in 1952(2), is due to the fact that for our study B can be treated as a single-design single-line factory[1] in that, broadly speaking, similar operations on different motors were done on similar equipment at a similar rate of work. But at C and at D the changes in output composition cannot be ignored. In C the effects were limited. In 1952(2), a period for which hours per motor are not available, the changes appear to have been sufficient in themselves to cause a 5 per cent rise in the time taken to make an average motor; but in all the other periods the changes were too small to alter the general picture of productivity changes given by the simpler figures of motors made per hour. But in D changes were large enough substantially to modify the general picture. The large apparent jump in productivity of

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[1] B produced other products on other lines. The attempt to measure productivity changes for factory B as a whole ran into serious difficulties, partly because advances in productivity for other products were substantially larger than for the motors considered here, but mainly because during the period a new line of product was introduced. Even after a full year, productivity in its manufacture remained well below target, and well below that achieved on the longer established products.

16 per cent between the two halves of 1953 is reduced to a mere 2 per cent and over the whole period the advance is reduced from 39 to 24 per cent—much nearer to the advances achieved in the other two factories.

Sources of Changes in a Single Line Factory

At this point we have to abandon the attempt at parallel development, since accounting differences between factories[1] make it impossible to analyse sources of change similarly in each factory. So let us begin with B, for which compositional changes were unimportant and where the detailed records are most informative.

In B a target time is fixed each year for every operation, and each month actual times taken are compared with target times. Actual time here means directly productive time, *i.e.* the time taken by direct labour when actually doing operations, and excludes idle time and time spent re-doing operations, both of which are included in our definition of total direct labour time. So we may distinguish three sources of change—changes in target times (target productivity), changes in the extent to which target times were achieved (target achievement), and changes in the ratio of ' non-productive ' time to directly productive time (other).

TABLE IX

Sources of Productivity Changes at B
(1952 (1)=100)

	Motors made per hour	*Average target productivity*[1]	*Average target achievement*[2]	*Other*[3]	*Errors etc.*[4]
1953 (1)	107	113	90	110	96
1953 (2)	106	113	89	106	100
1954 (1)	114	119	86	109	101

[1] *I.e.* the reciprocal of average target times.

[2] In 1952 (1) performance was on average 99½ per cent of the target, and so in this column the figure of 86 per cent for 1954 (1) means that on average performance was 85½ per cent of target.

[3] *I.e.* the effect on productivity of changes in the ratio of ' non-productive ' to directly productive time (see text for definitions).

[4] Column 1 is estimated partly from output records; but columns 2, 3 and 4 are derived entirely from input records. The two sources could not be made quite consistent owing to sampling fluctuations, changes in work-in-progress, changes in the proportionate importance of work on spares, etc. The effort needed to eliminate the residual items would have been of little value.

Figures on this basis are given in Table IX, from which it will be seen that, while between 1952(1) and 1954(1) target productivity was on average raised by nearly a fifth, the average rate of target achievement fell off by nearly as much. In 1952(1) performance was more or less on target with an average shortfall of no more than ½ per cent; but in 1954(1) the rate of target fulfilment was only 85½ per cent. On balance therefore the main source of rising productivity in this period was a cut in the proportion of non-productive time.

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[1] These, which originate largely in differing systems of payment, were described in our article I.

This is not a source that lends itself readily to detailed analysis; for the only relevant figures are departmental. Moreover in the period there was a re-organisation of the departmental structure, so that reliable departmental figures are not available for comparisons over time. Indeed we had difficulty in separating out figures for F.H.P. motor production, and the estimate of a 9 per cent rise in productivity from this source, attributable to a cut in the proportion of non-productive time from 29 to 22 per cent, is only approximate. The cut, which had occurred by 1953(1), seems to have affected most forms of non-productive time. The proportion of scrap went down; so did the much more important proportion of 're-operation' time, the time spent making good faulty work that did not have to be scrapped; and so did the proportions of various kinds of idle time—and, in particular, the time wasted by direct labour waiting while their equipment was re-set.

Cutting down reoperation and scrap was the most important of these savings, and we have specific evidence of two of the techniques used. One was the incorporation into the line of new testing points, an action likely to save re-operation work both by preventing further work being done on 'dud' parts, and by helping to identify possible sources of trouble more clearly. That the closer proximity of a tester also improved the quality of workmanship is a further possibility. The second technique was the inclusion of a few extra operations, commonly taking the form of a decision to achieve the same end in two stages; for instance, the operation of grinding the bore in an end-shield prior to inserting the bearing was split into two stages—rough bore and finish bore. Of course, the inclusion of extra operations added to direct working time, and this illustrates the danger of any too close identification of efficiency in the use of direct labour with saving in directly productive time.

We doubt whether these specific changes were the only sources of the improvement, and indeed the timing of the savings between the boom of 1952(1) and the slump of 1953(1) suggests a more general reflection. At B—but not at C or at D—the non-productive time of direct workers was treated as an overhead cost of manufacture, and it was not subjected to the detailed and continuous accounting check applied to directly productive time through the system of target times. During a slump, when the load of fixed overheads must appear oppressive, pressure to reduce overhead costs is likely to rise. Of course, in any factory a slump will increase the pressure to reduce costs; but there is some reason to expect that in a factory with B's accounting set-up there will be differential pressure on different parts of the direct labour bill at different times.

Such a source of advance in productivity must soon come up against limits. In the longer run, increased productivity has to come from the achievement of a higher target productivity, and we want now to turn to a study of the changes in target productivity. This proves more interesting than might be anticipated from the summary figures given in Table IX which suggest as an explanation of the change in target productivity the setting of unrealistic targets. Detailed examination however reveals sharp differential movements in productivity in different departments, which greatly alter the picture of ' no real change ' suggested by the summary figures. In the assembly department, where target productivity rose 28 per cent, actual productivity was unchanged because of a failure to achieve targets; but in the general machine shop, where target productivity rose by 22 per cent, actual productivity rose by 39 per cent as the raised targets were achieved even though those of 1952(1) had not been.

Figures for a single operation in the assembly department throw light on these differential movements. In B there was one operation of outstanding importance—that of inserting into the motor by hand the complex windings that carry the electric current. The operation is an exacting one requiring both strength and dexterity. It took some 15–30 minutes for an operative to complete the job on a single motor, and the rate of work varied sharply from operative to operative.

Between 1952 and 1954 target times for insertion were cut by 40 per cent—a very large cut. The cuts were not achieved. But a detailed analysis of some figures for April 1954 shows that the failure was to be attributed entirely to a high proportion of inexperienced workers. In this factory, new workers were initially sent to a training section off the main manufacturing lines where they were taught the rudiments of the job. Then after a period which varied from worker to worker they were transferred to the main lines; but for some time after that they were granted a series of concessionary bonus rates until they could reasonably be regarded as fully experienced. As a result of this difference in payments one can distinguish in the records between the performance of experienced and of inexperienced workers—the only direct evidence we have anywhere of the importance of this factor. The figures show that in this month experienced workers were working at a rate 15 per cent above the target; but that on average inexperienced workers, who made up fully two-thirds of the labour concerned, were working at only half this rate, with the result that *average* productivity was 17 per cent below the target.

A similar analysis for March 1953 reveals a different picture. At that time productivity was well above target: there were no inexperienced workers at the bottom of the slump. Thus, although between 1953 and 1954 *average* productivity on insertion fell sharply by 18 per cent, this was compatible both with a raising of targets by 10 per cent and with their achievement by experienced workers. The target revisions from 1953 to 1954 were not unrealistic, regarded as targets for the same workers: they became unrealistic only because output was rising faster than the productivity of the existing labour force, so that new labour had to be recruited.

The time taken for a worker to become fully experienced on insertion is measured in years and is longer than on most other operations. Against that however slow rates of work by some operatives are less likely to hold up the flow of production on insertion than on other operations with shorter cycle times. So the general failure in 1954 to achieve targets in the assembly

TABLE X

Analysis of Changes in Target Productivity at B for a Single Motor
(Total target hours in 1952=100)

	Target hours		*Net change*	*Target productivity in 1954 as percentage of 1952 level*
	in 1952	*in 1954*		
Operations with target times:				
Virtually unchanged	11.1	11.2	+ 0.1	99
Substantially raised	4.6	8.1	+ 3.5	56
Substantially reduced[1]				
insert windings	19.9	13.2	− 6.7	151
all other	18.8	12.5	− 6.3	150
Moderately reduced[2]				
in machine shop and diecasting	17.2	14.0	− 3.2	123
in assembly	27.4	23.1	− 4.3	119
All operations done in both periods	99.0	82.2	−16.8	120
Operations done in only one period	1.0	0.9	− 0.1	110
All operations	100	83.1	−16.9	120

[1] *I.e.* by more than 25 per cent.
[2] *I.e.* by less than 25 per cent and more than 10 per cent.

department—average performance in that department, which includes the insertion section, was 22 per cent below target—may be largely attributable to the influx of new workers, and therefore to the sharpness of the 50 per cent rise in output between 1953(2) and 1954(1). The contrast with productivity in the machine shop bears this out. In 1954 performance there was on target; but, because the machine shop serves all assembly lines and not just that for the motors we study, the influx of new labour there occurred in 1953(2) and in that period performance was 21 per cent below target.

Such figures underline only too clearly the dangers of snapshot pictures of productivity. The experience of B—the only well documented case—is probably not fully typical; for there greater emphasis was placed on the thorough training of labour with the result that the depressing effects of recruitment on productivity would be particularly marked. Anyhow, we may conclude from these figures that targets in this factory were, in spite of surface appearances, realistic as long as one abstracts from the effects of *short-run* variations in average quality of labour associated with recruitment. And so there is point in studying the details of target changes, representing as they do the kind of changes that in the *long-run* must be the main source of gains in productivity.

On average target productivity was raised by 19 per cent between 1952 and 1954; or, in terms of a more easily analysable figure, target times were cut by 15½ per cent. In Table X the cuts are analysed for a single representative motor, a procedure that is legitimate in this single-line factory. For a few operations target times were raised. In every case the rise was sharp and was associated with a major change in the content of the operation, the purpose usually having been the reduction of wastage rates. For another tenth of the required operations target times were more or less unchanged; but for the residual 83 per cent target times were cut sharply. In the Table we draw a line at the 25 per cent mark. Reductions in target times greater than this were—with the exception of the very important insertion operation—all associated with major changes in methods, such as the purchase of new types of equipment. Reductions of less than 25 per cent were not so associated, but correspond to increases in the target rate at which fundamentally unaltered operations were to be performed. On this basis major changes in the content of operations appear to have been comparatively unimportant. Indeed if, as would appear reasonable, one assumes that in the absence of major changes affected operations would have been speeded-up to the same extent as were unaffected ones, then the savings attributable to such changes would amount to merely 4 per cent and would in fact just counterbalance the increases in target times associated with the effort to cut down waste for certain operations. And so virtually the whole rise in target productivity of nearly 10 per cent a year is seen to have been due to a sharp rise in the target rate at which fundamentally unaltered operations were to be done.

The phrase ' fundamentally unaltered ' needs careful interpretation. At B there was a large and active work-study section. Using stop-watch techniques, engineers from this section studied in detail the actual movements of operatives, and used their results to suggest improvements. Some suggestions will call for the design of special tools and devices, *e.g.* special holders for the components being worked on. Others will call for changes in the layout of equipment—and, characteristically, expenditure on altering layout in this factory was high. Others still will not call for any changes in equipment, but only for a re-ordering of movements or re-arrangements of tools and materials used. But in all these suggestions the emphasis is on the extent to which examination of all the details of a given operation—and not just of the equipment—can reveal means of substantial improvement. And the operatives too were encouraged to participate in this task through a well-publicised suggestions scheme, in order not only to tap their ideas but also to rouse interest in the speeding of work. Naturally, it would be hopeless to try to isolate the effectiveness of these activities from all other means by which direct operatives were encouraged to work faster. Training in B was intensive, and incentive schemes were generous. But the experience of 1952–4 does suggest that, given the right conditions, rapid progress can be made by concentrating on improving the rate of performance of operations by detailed modification. The target rate of rise in this period was higher than can normally be expected; for we have little doubt that there was scope for particularly sharp improvements on the 1952 level of performance. But comments by the management do not suggest that in later years the pattern would have been all that different; for the process of cutting target times very year by 5 per cent or more continued; and, in contrast to 1954, in later years the normal thing was for the target to be achieved on average and not just by the experienced workers.

Sources of Change in a Multi-line Factory

C, unlike B, was a multi-line factory. From 1952 and until early 1954 there were three assembly lines; thereafter four. Comment on the new line, which was situated in another building, is postponed until later. Compositional changes in output were therefore potentially of far greater importance than in B. However they appear to have had only limited effects in the brief period covered by our survey, and adjustments to measures of productivity to take account of such effects did not substantially alter the picture given by the simpler figures of numbers of motors made per hour.

As we indicated in article I, several assumptions have to be made in calculating the likely effects on time taken of changes in output composition, and we therefore attempted by more detailed analysis to see whether the results of the calculations seemed to be more or less right. Our broad conclusion was that, in this particular case, reasonable results could be obtained by our techniques. But because, as we carried out this analysis, we came to realise just how easily this might not have been so, we want briefly to indicate why it was so.

The basic assumption used in the calculations is that, in assessing the likely effect on average times taken of compositional changes in output, one may treat times taken for individual motors as independent of compositional changes. This amounts in reality to two assumptions. The first is that the factory would not change the techniques by which particular motors were made in order to fit compositional changes. In practice, we found that this was indeed so, in this factory. For instance, in 1952(2), when the slump in washing-machine motor demand led to a sharp reduction of output on the two main manufacturing lines, output from the third special line actually rose slightly. No major transfers of motors were made from this line to the main lines, even though these would have been technically feasible. And, in general, there was, apart from specific improvements in techniques or designs, very little change over the period in the way particular motors were made. For this there were several good reasons. The first was that motors for small washing-machines—demand for which was growing fast—happened to be assembled on the same main line as was used for a wide range of standard motors—demand for which was declining. The second was that demand for special motors to be made on the third special line was restricted, as a matter of policy, to the capacity of that line, in order to prevent excessive variety in output from disorganising the flow of work on the main manufacturing lines. On these lines, with only six exceptions—all of them motors in high demand—output was restricted to standard motors all of which were manufactured for stock. Similar principles governed the manufacture of components. By these means it proved possible for the main lines to routinise the complicated business of deciding what should be made where and when, with the aim of achieving almost automatically most of the economies of scale implicit in the unity of design. Alterations to this routine, such as would have been involved in the transfer of particular motors from one line to another, must cause disorganisation; and the likely benefits would have to be substantial in order to justify such interference with established routine.

The second implicit assumption is far more difficult to assess. It is that changes in the rate of performance of operations in particular sections likely to arise from changes in the variety of such operations are roughly represented in the measures. That changes in performance would be likely to occur can be surmised from the lengths to which the factory went to reduce operational variety on the main lines. But they are in fact indirectly represented in our measures because of the tendency to set rather easier piecework prices on relatively uncommon operations, in order to prevent workers on lines with more varied outputs being penalised. On balance, we came to the conclusion that the indirect representation was probably about right—or to be more precise, that an over-representation of likely effects for machining operations was balanced by an under-representation for assembly operations. What is important about this conclusion is that it would not have applied had C used the forms of cost accounting used in either B or D. Thus we came to the conclusion that our measures were in this case more or less right, but only because:

(1) production of special motors was kept within the capacity of the special line;

(2) changes in the composition of output on the main lines were compatible with relatively unchanged allocations of motors to these lines;

(3) in this factory there were particularly strong arguments against making changes;

(4) the cost accounting was done in a particular way.

As we shall see, similar restrictive conditions were not satisfied in the other factory with a multi-line organisation.

Anyhow, however special the reasons, the measures are acceptable in this case, and we may get on to the analysis of why productivity grew by around 16 per cent between 1952 and 1954 in the old building.[1] The analysis is harder than for B; for with segregated facilities differential changes for different lines and motors were much more likely. As at B, the figures permit a somewhat analogous threefold division of productivity changes. C paid by the piece; and, since piecework prices were not normally revised unless there was a change in the content of operations, changes in them should provide a guide to the size and nature of changes in the content of operations. Piecework earnings per hour for similar grades of labour should provide a rough measure of average rates of performance on relatively unchanged operations; and finally there is again a residual item, corresponding roughly to the ratio of productive to total working time of direct operatives.

[1] In 1954 (1) low productivity on the new line lowered overall productivity by about 2½ per cent (see Table XII). The transfer of some key workers to the new line may also have been the cause of the slight fall (½ per cent) in productivity on the old lines between 1953 (2) and 1954 (1).

TABLE XI

Savings in the Content of Operations at C: 1952–4 (Old lines only)
(Total piece work cost for motor in 1952=100)

	Basic motor	*Average of other motors*
Savings due to:		
Re-design	1.0 (*17*)	0.8
Alteration of technique[1]	—	0.9
Mechanisation of previously manual operation	0.4 (*50*)	0.3
New faster equipment	1.4 (*14*)	1.1
Re-tooling of existing equipment[2]	0.1 (*100*)	0.2
Revised layout of existing equipment ...	1.4 (*17*)	1.0
Total savings due to changes in the content of operations if performed as specified in in the general instructions	4.2 (*17*)	4.3
Other savings in piecework costs[3] ...	−0.5	1.9
Total savings in piecework cost	3.7	6.2

Note. The bracketed figures show the saving as a percentage of the time of the operations involved.

[1] *I.e.* Substitution of dipping for spraying as the technique for painting a certain type of component.

[2] The operation concerned—chamfering a sharp edge on a shaft—was incorporated into the cycle of the main turning operations on the shaft.

[3] *I.e.* changes due to re-grading of operations, changes due to re-negotiation or arbitration of piecework prices, and changes due to variation in the gap between piecework prices as officially laid down and those actually paid on average (see text).

But only the first of these categories can be further sub-divided according to kind of motor; and so any analysis of differential changes for different kinds of motor has to be confined to comments about changes in the methods used to make them.

Even then the snags that arise in deriving the information shown in Table XI are formidable.[1] As it happened the savings for the common washing machine motor—the basic motor assembled on the fastest line—turned out, after elimination of changes in piecework payments not associated with changes in the official methods of manufacture, much the same in percentage terms as those for an average motor assembled on the second main manufacturing line.[2] Roughly three-quarters of the operations had unaltered piecework prices; on the remainder a saving in time of 17 per cent gave an overall saving of 4 per cent. The detailed analysis serves to show how various

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[1] The main source of trouble is that for machining operations actual piecework payments were on average about 10 per cent higher than the minimum payments that would have been made if every operation were done in the way it was supposed to be done according to the general instructions that specified where particular motors and components were to be made. Some of the excess arose because men had to be employed on operations officially graded as women's or boy's work, some arose because owing to machine break-downs or shortage of capacity operations could not be done where they were supposed to be done, and some arose because foremen had the authority to increase piecework prices to take account of any special circumstances that may have made the job harder than normal. But no records existed to indicate which of these factors contributed most to changes in the excess. Therefore one has, in interpretation, to allow for the fact that there are serious gaps in one's knowledge about the *actual* content of operations performed.

[2] For individual motors the percentage saving varied between 2½ and 8½.

TABLE XII

Sources of Productivity Increases at C, 1952–4

Gains attributable to:	
changes in the content of operations...	+4
factors giving rise to enhanced piecework payments per hour	+8[1,2]
other factors	+4[1]
Total increase on old lines	+16
less effect of low productivity on new line	−2½
Total net increase	+13½

[1] Both these measures are subject to an error margin of 1–2 per cent.

[2] *E.g.* greater effort or aptitude, better organisation and supervision, more daywork, etc.

are the means through which the content of operations may be cut down. The pattern was one of detailed improvement on existing techniques—changes in layout, tooling and in the provision of aids accounted for nearly half the expected savings. Fundamental changes in the content of operations were even less important than at B.

The other sources of rising productivity were statistically more important, and accounted for about 12 per cent of the total improvement. Table XII gives the best analysis we could manage. As at B the residual item at 4 per cent was important, although not so important, since at C there was no room for any marked reduction in scrap and re-operation rates.[1] The measured change in ' rates of work ' was 8 per cent; but unfortunately this figure cannot be analysed by line[2]—let alone for particular motors. But some comments concerning the make-up of direct labour hours can indicate some of the possible sources.

Because in C the slump in output was mild, there were few redundancies, and there was therefore no sharp improvement during the slump in the average ' quality ' of labour. The advance in productivity followed the more familiar pattern of a sharp improvement in the early stages of recovery. Productivity rose by only 3 per cent between 1952(1) and 1953(1), but then jumped by 13 per cent between 1953(1) and 1953(2).[3] But there were other changes in the composition of the labour force which are relevant to an assessment of the 8 per cent rise in work-rates. During the slump the proportion of men employed rose, and it did not fall again significantly during the recovery, so that in 1954(1) the proportion of hours worked by men was, at 45½ per cent, 5 per cent higher than 1952(1). Such a change would, given the observed average differentials of men *vis-a-vis* women and *vis-a-vis* boys,[4] have raised the average cost per hour of direct labour by about 3½ per cent. How far the switch to men was responsible for the rising rate of work it would be impossible to say;[1] but some connection there probably was.

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[1] See pp. 258–9.

[2] In 1952 the payroll was not ordered in such a way as to permit the calculation of average piecework earnings per hour on separate lines. Fragmentary evidence suggests that the improvement in rates of work was smallest on the second main manufacturing line where a limited list of motors was assembled.

[3] This different pattern may have been linked with another facet of organisation. In C the individual operative—at any rate in the old building—had relatively greater freedom than in either B or D to set his own pace of work, and thus was more independent of short-term pressures from supervision.

[4] The average differentials in earnings per hour were considerably wider than those in nationally-negotiated rates.

The same is true of another aspect of the composition of direct labour input—that concerning times of work. In 1952(1) all the main manufacturing lines were worked on the double-day shift system. In October 1952 shift-working was suspended, to be resumed again by stages from July 1953. By 1954(1) it had been resumed on all but the second assembly line, though the new line was also not working shifts. We have been told that the working-up time on a morning shift beginning at 6 a.m. is longer than on a working day beginning at 8 a.m. If so a decrease in the proportion of shiftwork—and, because of fatigue, the same would be true for a decrease in overtime work—would be likely to be accompanied by some rise in the average rate of work.[2] Suppose the rise to be expected from a complete switch to day-work from shiftwork was as high as 5 per cent. If it were, then this would alter the picture of the timing of the advance in productivity. The apparent increase of 3 per cent between 1952(1) to 1953(1) would have to be attributed to the switch to day-work, so that all the real advance was concentrated in the recovery.[3] And it would also serve slightly to qualify the 8 per cent advance achieved over the whole period, because 1 per cent would have to be put down to the absence of a full resumption of shiftworking by 1954(1).

It seems, therefore, that all the changes in the composition of the hours worked were of a kind which would of themselves be expected to raise the average rates of work. On the other hand, the concentration of managerial effort on bringing in the new line—and the transfer of some key workers to it—must have served to hold down the rate of increase, making it impossible to guess how far the rate of increase actually achieved was one that could be maintained in the longer-run.

The New Line at C

And now finally a brief comment on the new line, which was brought into operation in early 1954. In several ways its organisation represented a major departure from previous practice. In the old building all standard major

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[1] Men earn more than women per hour largely because piecework prices for operations are worked out on the basis that a semi-skilled adult male worker 'of average ability' should be able to earn about 80 per cent more in piecework payments per hour than should a semi-skilled female worker 'of average ability'. In practice, the average differential is over 100 per cent. constituting some evidence of rather dubious reliability that on average men in this factory do work rather faster than women.

[2] Some sampling of payrolls seemed to confirm that the existence of such an effect; but the variations in work-rates from week to week on particular lines were too large to permit any firm conclusions.

[3] This, as all other references, applies only to advances in productivity *per man-hour*. A switch to shiftwork cuts the standard working-week by 15 per cent from 44 to 37½ hours, and so sharply reduces productivity *per man-year*. So p.m.y. in C was definitely much higher in 1953 (1) than in 1952 (1)—a fact reflected in a sharp cut in 1953 (1) in the cost of premium payments per hour worked. (In the day-working factories B and D, the cutting out of overtime in the slump reduced both p.m.y. and the cost of premium payments). These comments are obviously relevant to any overall assessment of performance in any factory; but, since the purpose of both shiftworking and overtime working is to apply more direct labour to the same equipment, and thus to substitute premium payments to labour for overhead costs, they are not usefully analysed in the context of direct labour alone.

TABLE XIII

Expected and Actual Times on New and Old Lines at C
(Times on old lines=100)

Savings in expected times[1] *on new line:*		*Basic motor*	*Other motor*
Major savings on both motors		+4½	+4
Major savings for other motor only		—	+2
Time averaging[2]		−2	+1¾
Minor changes[3]		+2½	+3
Total expected saving		+5	+10½
' Rate of work ' on new line relative to that on old lines[4]	1954	81	78
	1955	86	85
Actual time on new line relative to that on old line... ...	1954	117	114
	1955	111	105

[1] Expected times are based on piecework prices after allowance has been made for differences in levels of piecework prices for different grades of labour.

[2] On the operation of inserting windings by machine there was a differential in the old building but not in the new, the new piecework price lying between the two old ones.

[3] This item includes an allowance for the likely effect on times of the installation of the moving conveyor.

[4] *I.e.* ratios of piecework earnings per hour for similar grades of labour.

components had been made for stock; but in the new building three parallel manufacturing lines—one for assembling stators, one for machining rotors, and one for machining endshields—led up directly to a main motor assembly line, with provision for temporary stockholding only. This form of layout cut the average size of batch to be made, particularly on the two machining lines; and, in order to minimise the disturbance associated with variety, much detailed engineering planning was devoted to eliminating differences between operations on rather similar motors. Gadgets were designed to eliminate the need to re-set equipment for slightly different components. Changes were made in the detailed division of operations between workers, so that the time needed for successive operations was evened out. This allowed the lines to operate rather more as flow lines than had been possible in the old building, and a moving conveyor was installed to pass components from one worker to the next.

The expected results of these changes—and of the other improvements introduced—are illustrated in Table XIII. For the basic motor the expected saving in time was 5 per cent as compared with the same motor made in the old building—making in all a saving of 9 per cent in comparison with the same motor as made in 1952. For the more complicated motor the expected saving, in line with the policy of evening out times, was even larger at 10 per cent. But even for the latter motor the expected savings were not due to fundamental changes in methods. The principles of organisation were new; but the basic techniques used on the new line were similar, and the saving was to come largely from detailed improvements in tooling, layout and gadgetry. C, unlike B, had no work-study department; but it did have a special engineering section working on methods development. Often enough its work led to the same sort of improvements as in B—the development of special-purpose devices, the detailed re-arrangement of the layout of equipment etc.; but there was at C a rather greater emphasis on eliminating work than on speeding it up. Indeed the contrasts between the factories would probably be much more marked in some period in which the detailed work of C's methods development section had not, as in 1953–4, been so largely directed towards planning the new line, particularly since many of the detailed improvements made there were of a kind that could have been introduced on the older lines without major re-equipment.

The expected savings in time were not in fact realised. Piecework earnings per hour for similar grades, a rough guide to rates of work, were substantially lower on the new line than in the old building, and remained so even after the former had been in operation a full year. One major reason was the inexperience of the labour employed there. Some experienced workers were transferred from the old lines; but the new line was largely manned by freshly taken-on labour, with inevitable consequences for the average rates of work achieved. But this was not the only cause of the continuing low rates of work. Probably as important was the fact that the whole organisational set-up differed sufficiently from the one that was familiar to management and workers for a lengthy working-up period to be inevitable.[1] As would be expected, experience in working the new line did lead to some organisational changes, mostly in the direction of increasing its resemblance to the older organisation,[2] and incidentally reducing its resemblance to B's organisation. There is here a point of considerable general significance. As time passes, workers and management gain experience in making a particular set-up function smoothly—and particularly in coping with the problems arising from the variety of operations to be done on one line. But much of this acquired experience will be specific to the particular set-up, and any major departure from previous practice must involve some dislocation, while the required experience with the new set-up is gathered. In productivity comparisons over a short period, the dice are therefore loaded against major departures from current practice—and, in particular, against the kind of experiment with new forms of organisation which C tried. This should not, of course, lead one to conclude that detailed improvement within a basically unchanged pattern is necessarily the best way of securing productivity increases over a longer span of years. Obviously it is not; but the fact is that the gains from fundamental departures from existing practice are unlikely to be gathered in the short-term, unless indeed the existing practice was proving manifestly unsuccessful.

Sources of Change in a Multi-Product Factory

D, unlike B and C, made its induction motors to a variety of designs. We have already seen how in shaft manufacture this variety greatly complicated its manufacturing task in 1955. At that time it had five basic designs; but the special-purpose design, D1, for washing-machine motors had only been introduced the previous year. Before April 1954 output consisted entirely of motors of general-purpose designs; and so our study falls into two distinct parts. The first part is a study analogous to those already done for B and C but one in which, because of the multiplicity of design, changes in the composition of output had larger effects. The second part is a study of the effects of a major change in design and organisation, and as such has considerable analogies with inter-factory comparisons. This latter study we postpone, noting merely that the immediate effect of the change on *overall* productivity was negligible. This has the convenient consequence that we may in the first study use figures for overall productivity in 1954 (1) as if design D1 had not been introduced.

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[1] *Cf.* the new product at B, productivity on which likewise remained well below target after a full year of manufacture. See p. 217, footnote.

[2] One change concerned methods of payment. In the old building piecework payments had usually been based on the output of individuals; but, in view of the more flow-like characteristics of work on the new line, it was decided to base them on the output of groups. Experience showed that in this factory such payments were a less effective incentive, and so the size of the groups for assessing these payments was sharply reduced.

In 1952 (1) nearly 80 per cent of output of induction motors consisted of motors of design D2—the design similar in size and purpose to the single designs at B and C. The manufacture of D2 motors was divided. The bulk, consisting largely of washing-machine and refrigerator motors, was assembled on one line; the residue were assembled on other lines, output from which was split about half and half between D2 motors and those of the other designs, D3 to D5.

The slump brought some drastic changes in the composition of output, but, as at C, there were no major changes in the routing of manufacture. The proportionate importance of the slower lines rose sharply: in 1952 (1) three out of every five motors were made on the fast line; but by 1953 (1) the proportion was less than one in two. In addition, output from the slower lines became more complicated. In 1952 (1) half their output consisted of D2 motors, but in 1953 (1) the proportion was down to two-fifths, and, owing to the ending of relegation, that two-fifths was rather more varied than it had been.

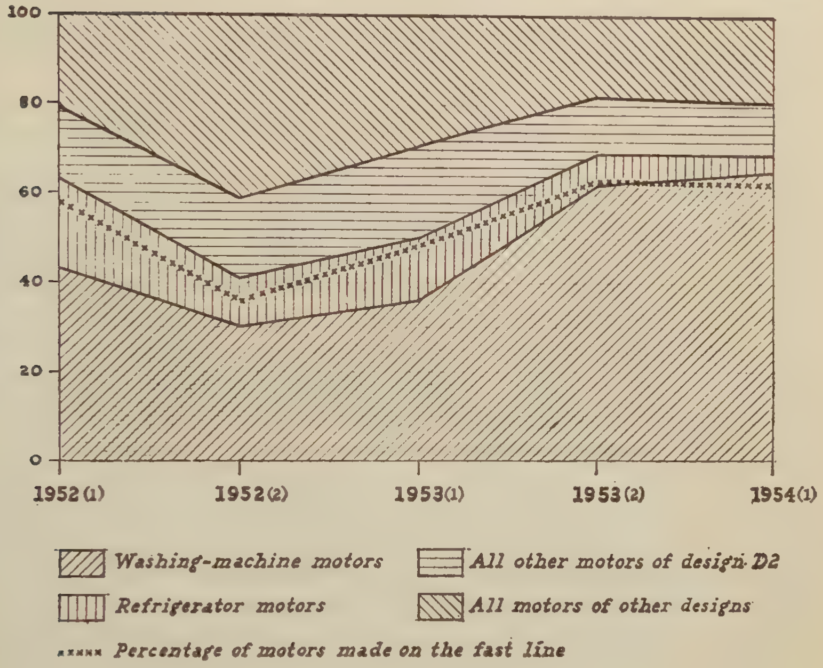
In 1953 (2) output of washing-machine motors—but not of other types—recovered. Owing to an innovation in refrigeration design, output of refrigerator motors continued to fall. As a result, although the division of output between lines returned to one similar to that prevailing in 1952 (1), the structure of output on the faster lines was by then quite different. Whereas in 1952 (1) washing-machine motors had been only twice as common as refrigerator motors, in 1953 (2) they were nine times as common.

These large shifts are illustrated in Graph I; but the graph does not fully bring out the degree of polarisation in markets that had occurred. It does show the decline of the bulk market for refrigerator motors, with its consequent effects on the degree of variety of output made on the faster line; but it does not show that over the same period output from the other lines was becoming still more varied. Here some comparisons with developments at C are relevant. At C there was also some polarisation of markets from 1952 to 1954. The proportion of washing-machine motors rose from 62 per cent in 1952 to 74 per cent in 1954; but in the remainder of output the proportion

Graph I.

Changes in the Composition of Output at D

(Percentages of total output.)



of what are classified at C as ' standard ' motors fell from 69 to 62 per cent. But for design D2 the effects were far more pronounced. The proportion of washing-machine motors rose from 49 to 78 per cent, and in the remainder the proportion of motors equivalent to what would at C be classified as ' standard ' fell from 73 to 36 per cent. So by 1954 demand for D2 motors had become sharply polarised—far more so than C's demand—between, on the one hand, a bulk demand for washing-machine motors and, on the other, a very variegated market for all other types.

These facts formed the background to the decision to introduce the special-purpose design D1, specifically intended for washing-machine use; but they also had considerable effects before that decision. According to our measures (see Table VIII p. 217), the likely effect of the changes in output composition was a reduction of over 10 per cent in the average time taken to make a motor. In consequence, the adjusted measure for the growth in productivity between 1952 and 1954 was, at 24–5 per cent, much less than the 39 per cent growth in the number of motors made per hour. Furthermore, our measures probably underestimate the simplification of output which occurred.

As at C, one may accept as reasonable the assumption implicit in our measures that individual motors were made in the same way in the two periods. Output on each line consisted of much the same range of motors throughout, and the relative importance of the two lines was allowed to fluctuate widely, and was indeed the main source of the sharp changes in the measures over the period. In effect, as at C, the disadvantages associated with major changes in the routing of manufacture were held to outweigh the potential advantages of re-organising manufacture to fit in with the changed composition of output. But the other main assumption concerning the likely effects on rates of work of changes in the variety of output within lines is more suspect.

First, because of the form of cost accounting at D, there is no reason to suppose that such effects are reflected in our measures.[1] Second, the likely effects were much larger than at C. Although there was little change in the range of motors made on each line, and therefore in the range of operations to be done in any section, the proportionate importance of less common variations did alter substantially. It fell sharply on the fast line, and rose elsewhere. We believe the former change was more important than the latter, and that the adjusted measure of 24–5 per cent for the growth in productivity between 1952 and 1954 is somewhat too high.

There is therefore some doubt about the magnitude of the overall increase in productivity; but the main problem in the study of D is that of identifying the sources of the sharp increase which undoubtedly occurred in this period.[2] The increase in productivity was over 20 per cent in all but three of the thirteen major manufacturing sections into which the factory is divided for purposes of cost accounting. All these three sections were situated on the slower lines, a fact which leaves no room for doubt that variety in output was a crucial factor influencing rates of growth. But one cannot determine to what extent these low rates were due to the *increase* in variety; all that can definitely be said is that productivity was sluggish where variety was high and increasing.

In seven sections the rise in productivity lay between 20 and 30 per cent, and in three more it was over 40 per cent. No detailed analysis of these figures proved possible. In particular, we could not *measure* changes in the content of operations, although we do know that in two of the three sections with rises of over 40 per cent the source was largely such a major change. But not in the third—motor assembly on the fast line. There the source seems to have been a very sharp rise in the rate of work. On this line motor assembly was progressive, *i.e.* the operation of assembly was sub-divided in such a way that each operative did one particular part of the operation on all motors assembled on the line. At B and at C, on the other hand, a single operative did most of the job. The *pros* and *cons* of these two organisations are numerous, but experience has shown that at D such an organisation can substantially raise the average rate of work,[1] and gradually therefore the principle has been extended to more and more sections. We do not know how important such extensions were in 1952–4; but we have no doubt that in this period what progress was made in raising the rate of work was largely made where progressive organisation of work was possible, and that therefore the changes in the structure of output which were reducing variety on the fast lines were of substantial importance in explaining how D in this period managed to achieve a rate of growth in productivity that considerably exceeded those achieved in B or in C.

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[1] At D, the cost of a group of operations on an individual motor is estimated by spreading the total labour cost incurred in any section over the motors made there according to technical coefficients based on time-study. In consequence, within a section, but not between sections, the extra costs associated with disorganisation due to variety in product are spread evenly between all motors made there and, not as in C, more to odder motors than to less odd ones.

[2] D does not operate any form of payment by results, and in consequence it is impossible to draw the kind of threefold distinction between sources of productivity growth which could be drawn in the other two factories.

The Effects of Re-design

Even so in early 1954 D, in spite of the considerable progress since 1952, remained a relatively unproductive factory. Motors made on the slower lines took far longer to make than their equivalents in either B or C; but that was scarcely surprising in view of the far greater variety of operations to be done there, arising from the multiplicity of design and of markets.[2] But much more significant is the fact that even motors made on the fast line were also made much more slowly than their equivalents on B or at C.[3] Furthermore the lower productivity was pervasive. For instance, in early 1954 the figures show that with one exception[4] B was more productive in every group of operations required to make the basic motor, even though at B there was no segregation of facilities that would tend to speed up the manufacture of this motor, and even though the equipment in use at B was, on balance, of a less labour-saving kind. Nor can much of the low productivity be attributed to the greater complexity of design of D2 motors. The main reason was undoubtedly the simple fact that at D similar operations on similar equipment were done—even on D's faster line—at a rate lying somewhere between a half and two-thirds of B's rate.

The task involved in raising productivity at D was therefore of a different kind from that in either B or C. In those factories, it was reasonable to

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[1] Such an organisation is sensitive to variations in speed of work between operatives. Obviously a flow-line system can hold up fast workers, as well as spur slow ones, and would probably therefore be inappropriate in a section, such as the coil-insertion section at B, where differences in the rates of work between fully experienced and other workers are immense. Even at D similar effects were important. In 1953 (2) productivity was (after adjustment for change in composition) on average little higher than in 1953 (1), probably because the flow of work was being held up by a large influx of new labour. But by the turn of the year, it was up sharply, suggesting that, while the immediate effect on productivity of recruitment (and conversely of declarations of redundancy) were probably as sharp as at B, they persisted less long.

[2] The shaft study give a somewhat extreme picture of the effects of variety on productivity; but it was not essentially misleading.

[3] See Table XVI.

[4] The exception is due to a major difference in design.

TABLE XIV

The Effects of Re-design and Re-organisation on Times taken to make Motors at D
(Time taken to make a washing-machine motor in early 1954=100)

	Early 1954	*Mid-1954*	*Mid-1955*	*Percentage change in productivity: early 1954 to mid-1955*
Washing-machine motor... ...	100	93	79	+26
Small refrigerator motor... ...	115	158	154	−25
Large refrigerator motor ...	163	176	173	− 6

proceed by means of detailed improvements on existing patterns of organisation and techniques; but in D the facts called for more fundamental changes, which were bound to take a long time to carry through. The first step, taken in 1953, was greatly to expand the staff responsible for the planning of the manufacturing process by setting up a separate engineering development section. The second step was the introduction of the new design D1 together with the more or less complete re-equipment of the line to make it. The third and subsequent steps in which the rest of manufacture was reorganised lay outside our period of study.

The savings apparently associated with the new design were great. After it had been running for only two months, washing-machine motors were being made 7 per cent more quickly than immediately before the change, and one year later, when the inevitable running-in period was past, the saving in time had risen to 21 per cent.[1] In part these savings arose from the re-design itself. The greater structural simplicity of the new design, which allowed an 8 per cent saving in material usage,[2] also allowed a number of operations to be cut out or simplified. In part also they were due to the accompanying re-equipment. Much of the machinery used for the new design was new, and was on balance considerably more automatic than the corresponding equipment used for the old design. Together these sources of saving amounted to well over 10 per cent on the content of operations to be done; but it is impossible to estimate how far it was the re-design, rather than the accompanying decision to segregate manufacture of the new design entirely, which permitted the greater degree of automatisation.

In mid-1954 actual savings in time on washing-machine motors were below the savings attributable to these technical changes; but by mid-1955 the actual saving in time was 6–10 per cent higher than can be explained in terms of the changed contents of operations alone.[3] This saving has to be set against the dissavings elsewhere; for the re-organisation had the result of sharply increasing the time taken to make every other type of motor, the

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[1] Productivity on the new design at D, unlike that on the new line at C, was not held back by an intake of fresh labour. D allocated the best operatives to work on the new design.

[2] See article II, p. 116. As we pointed out then, only some of the savings from redesign could be attributed to the decision to *specialise* design.

[3] This estimate is probably correct; but it is based on time-studies of a later period, by which time the engineering development section had had time to get round to the study of the lines making D2 motors.

TABLE XV

Analysis by Section of Productivity Decline at D

Group of operations	*Number of manufacturing sections before re-organisation*	*Proportion of ' other ' motors or their components made in faster section before reorganisation*	*Average time taken on ' other ' motors before reorganisation as percentage of average time on washing-machine motors*	*Percentage increase in average time taken on ' other ' motors following re-organisation*
Build stator	1	100	113	+31
Machine and assemble rotor	1	100	101	+35
Machine endshields ...	2	56	123	+17
Assemble stator	2	8	157	− 7
Assemble motor	2	10	125	− 2

Note. ' Other ' means motors of design D2 (though not of other designs) other than those for use in washing-machines, *i.e.* those whose designs were not affected by the introduction of design, D1.

designs of which had remained unaltered. For a few motors the rise was particularly sharp, as much as 37 per cent; but for all there was a rise of at least 8 per cent, and in mid-1954 these losses just about balanced out all the gains on the new design. Nor were these losses transient. Even a year later productivity on these motors of unchanged design remained well below that achieved in early 1954, and the losses were still nearly enough to offset the gains from the higher rate of work on the new design.

Table XV presents a more detailed analysis of the sources of the rise in times for these motors of unchanged design. In the assembly sections, in which even before the re-organisation the faster line was already being used mainly for washing-machine motors, all that occurred was the relegation to the slower line of the residual 8–10 per cent of the non-washing machine motors made there together with the promotion of a rather similar proportion of washing-machine motors. Effective re-organisation was slight, and there was a slight rise in productivity on the slower lines. But in machining sections the effects were profound. In one section where production had been segregated before the introduction of the new design, average times rose by a sixth[1]; and in the two which had previously been unitary in organisation (either for output as a whole or for all output of design D2) the rise was about a third.

The net result of these changes can be summarised briefly by the comparisons with B shown in Table XVI. Before the introduction of the new design D's productivity was much lower than B's for all motors. After the introduction of the new design and the associated re-organisation, productivity

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[1] This rise was a direct example of the loss from reduction of standardisation. Many other types of motors carried the same endshields as washing-machine motors of design D2, and before the change 86 per cent of endshields were made in the faster section. After the change new equipment was installed for the endshields of design D1, and throughput on the unchanged equipment in the old faster section fell to 11 per cent of total factory output of endshields.

TABLE XVI

Ranges of Direct Labour Productivity for Different Designs: B v D
(Productivity at B=*100)*

Design at D	*Before introduction of new design (early 1954)*	*After introduction of new design (mid-1954)*
D1	65—75[1]	85—90[2]
D2	50—75[3]	40—65
D3	55—60	45—55
D4	40—30	25—35

Note. In this table no adjustments have been made for 'transfer effects' (see article II, pp. 111–2). Consequently, all figures are too favourable to D by c. 10 per cent. In addition all figures are subject to considerable margins of error.

[1] *I.e.* washing-machine motors of design D2, which were later superseded by motors of design D1.

[2] By 1955 productivity at D on these motors was 18 per cent higher. No corresponding figure for B was obtained.

[3] *I.e.* all but washing machine motors.

on washing-machine motors rose towards B's level, but only at the expense of widening still further the already large gap for all other types of motors. On D4 motors the gap was gigantic;[1] but even on D2 motors, where there was a basic similarity in size and purpose of design, the differences in productivity were very substantial.

It is only too easy to calculate measures which give quite the wrong impression of the advantages of the redesign and the associated re-organisation. Consider, for instance, the calculations of Table XVII, in which overall comparisons are made between productivity in mid-1954 and productivity in 1952. The first column is just a repeat of that already given in Table VIII and shows that productivity in mid-1954 (subject to qualifications made earlier about this measure) was 24–25 per cent higher than it would have been in making the same output in 1952. But the second column shows that an increase only half as great would have been achieved if in 1954 output had been of the same composition as that produced in 1952. But such an estimate is of significance only if the output concerned was one that D might in the future have been called on to make: *i.e.* only if the process of polarisation in output described earlier was likely to be reversed.

Although we made no direct study of markets we are fairly certain that such a reversal was unlikely. Fluctuations in Government hire-purchase policy would in the future alter the balance between washing-machine motors and others with inevitable consequences for the factory which had specialised in the design and manufacture of the former. But we see no reason why the other aspect of polarisation—the growing variety in the rest of output—

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[1] The issues involved in such a comparison were discussed in article II pp. 126–7. Essentially the point made there was that the range of uses covered by B's design was slightly larger than the range covered by D2, so that for a limited number of uses a B motor was equivalent to a motor of design D4, which was much larger and required 25–50 per cent more material. The table shows that on labour the difference was even more marked, D using 3–4 times as much labour, so that the competitive advantage in this limited field that B derived from the stretching of its design was even more marked than suggested in our last article.

TABLE XVII

Alternative Measures of Comparative Productivities at D (mid-1954 as percentage of 1952 (1))

	Comparative Productivity in making:	
	1954 output	*1952 output*
Number of motors made per hour	139	
Hours required per motor[1]	89–90[2]	81[3]
Productivity adjusted for differences in output composition	124–125	113

[1] For definition of this item, which is an estimate of the effects on times of differences in the composition of output, see note to Table VIII.

[2] Calculation based on relative motor costs in 1952. This figure is the one shown in Table VIII.

[3] Calculation based on relative motor costs in mid-1954, *i.e.* after the introduction of the new design.

should be reversed; for it seems unlikely that this trend was unconnected with structure of costs in D. On D's organisation before the introduction of the new design, all but a limited range of motors of design D2 were made on the same line as motors of different designs, with the consequence that they had in fact largely to be made as if they were ' specials '[1]; and it would indeed be odd if D's particularly heavy losses of markets for motors of this type in the period of fierce competition engendered by the slump of 1952 had been wholly unconnected with this fact. In other words, we believe this to be another instance of the strength of the forces that work towards *de facto* specialisation in a multi-product industry.[2]

The consequences of this kind of specialisation are quite far reaching. If a factory is ill-suited to make standard motors because it has to make them as if they were specials, it will as a result be able to make special motors on a scale that might throw either of the other two factories into disarray. Technically it may appear unproductive; but it should be in a position to cater for customers who want and are prepared to pay for specialities. One might indeed argue that often the desires of such customers for special variations may be the result of their inefficiency in design, but given a structure of prices in which motors whose manufacture can be standardised are bound to sell at prices lower than those whose manufacture cannot, there are some advantages in becoming a specialist in the latter kind of motor, advantages of a kind which do not show up in our kind of productivity measures.

Without an enquiry into markets, selling prices, and selling costs one can give no indication of the size of these advantages; but to concentrate on this aspect would be to miss the most significant implication of the comparison. There was in 1952 no sign that the especially low productivity on standard motors other than washing-machine motors was the result of a deliberate decision to organise manufacture in such a way as to specialise on washing-machine motors or on special motors. Rather it appears to have resulted from decisions as to how best to organise manufacture in such a way as to achieve economies of scale, given that motors of several designs—most of them in rather low demand—had to be made, and given that certain types of motors were in high demand. But, because of the decisions, certain markets tended to be lost; with the result that, given the simultaneous decline in general demand for refrigerator motors, output had by 1954 become so polarised as to justify deliberate specialisation. In the manufacture of washing-machine motors, where the market itself supplies the scale to permit long runs, and of very special motors, the characteristic expedients used at B or at C to reduce variety to a tolerable level—design and operation standardisation, motor and component stocking, segregation of specials—would be of much less use than in the middle part of the market for standard and near-standard motors. Thus the failure of D to solve its manufacturing problem was gradually forcing it into a position where the solutions adopted at B and at C were becoming powerless to help, because its lesser disadvantage in specials meant that it was obtaining proportionately too many such orders for any expedient to reduce the variety of operations to have much success.

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[1] The lack of detailed standardisation within D2 was also important.

[2] *Cf.* article I, p. 157 and article II, pp. 117–8.

We conclude that by 1954 D had the kind of markets to which neither B's nor C's approaches were appropriate. It had, in short, the markets to which its action in introducing D1 was the obvious solution, with the consequence that assessments of its action which are based on the assumption that it might have had another market miss the point. But it is also more than a matter of markets. D was, even in early 1954, relatively unproductive. One obvious way to set about remedying this was to concentrate on some isolable part of its problem, and so to establish within the factory an area of high productivity which might serve as a standard of performance for the time when a more comprehensive approach became practicable. By so acting, it temporarily made worse its problems outside that area, so that the immediate overall gains were far from striking, and were peculiarly dependent on a certain structure of markets, But it did at the same time build up a body of experience which could be applied in later years to the far more difficult problems posed by the rest of its output.

This picture is one of considerable significance. One of the common comments about British industry concerns the range of performance of factories within the same industry. It is often remarked that if only standards in the less productive factories could be raised some of our economic problems would be solved. The statement is incontrovertible; but it conveys a false picture of the size of the problems that are likely to face the unproductive factory that sets out to narrow the gap. D had a way out; the relative growth of mass markets created the possibility of achieving higher productivity by design specialisation. But even so, because of its earlier poor performance, it inherited a manufacturing problem of inherently far greater difficulty than that of either B or C, and it seems to us that the same kind of market forces are likely to operate in other industries, with the effect that the unproductive factory is always likely to face a manufacturing problem that may rule out the approaches that have made the more productive factories as productive as they are. For they are likely already to possess, not only the know-how but also the markets on the basis of which a steady programme of improvement of their chosen organisation can be implemented.

The Utility of Inter-temporal Comparisons

In these three studies, our aim was to measure, and identify the sources of, changes in productivity over a brief period of 2½ years. We do not want at this stage to generalise about these sources; we will confine ourselves to a brief comment on the practicability and utility of inter-temporal comparisons of productivity in multi-product factories. Crude measures of productivity changes, derived by comparing changes in hours worked with changes in some simple physical measure of output such as numbers produced, will usually be easy enough to compute; but they may be very misleading indicators of performance. Simple measures of output must be suspect in multi-product factories, in which there are bound to be some changes in the composition of output over time. The real difficulties of measurement begin when the attempt is made to measure the likely effects on performance of the changes in output composition. Each of the factories we studied produced hundreds of different motors: output records had to be sampled, and individual cost figures obtained for all motors in the sample. The simplicity of the crude measures is lost, since different measures for the likely effect of changes in output composition may well emerge, as cost figures for different periods are used as the basis for calculation. Furthermore, the resulting measures are hedged around with a variety of qualifications, all of which could be important: and only detailed investigation can indicate whether or not the measures are misleading.

In particular circumstances, it may be possible to accept, as indicators of performance, the crude measures of productivity, and so avoid these complexities. Evidently this can be done if the composition of output from a factory has not in fact changed over the period studied. More important, it can be done if the factory has organised its production in such a way that the likely effects on performance of changes in output composition are slight. B was a case in point. All motors were produced in much the same way on a single manufacturing line: within rather broad limits compositional changes would not matter, and the compositional changes which did occur were not great. The whole framework of measurement for changes in output composition turned out to be unnecessary. Both C and D, however organised their production in such a way that changes in output composition could markedly affect performance. Manufacturing facilities were segregated, and different techniques were used for different motors. Our measures of the effects of compositional changes suggested that the effects at C were not great, but that they were substantial at D. There, our adjusted measure of productivity change over the period was 24–25 per cent, in contrast to the crude measure of 39 per cent. Detailed investigation indicated that the measures of adjusted productivity at C were on balance about right as a measure of the improvement in performance over the period; but only because of a considerable measure of organisational continuity in the face of compositional changes, and because the detailed way in which direct labour usage was accounted for happened to be appropriate for the sort of calculations we made. At D, however, there were major organisational changes over the period, and the cost accounting system was not very suitable for our calculations. Alternative measures for the growth of (adjusted) productivity diverged rather widely, and none was wholly satisfactory in measuring what it purported to measure. It is relevant to note that in any longer-period comparisons, D-like cases will be more numerous that in short-period comparisons: the measures are likely to deteriorate in quality as the intrinsic interest of the comparison increases.

Success in identifying the sources of productivity growth will depend partly on the availability of detailed records disclosing the way in which direct workers spent their time. The effects of specific changes, such as those affecting the content of the operations to be done, can often be isolated: though if detailed accounting is as rudimentary as it was at D, even this may not be possible. Our experience with these factories, however, suggests that specific changes of this sort may not turn out to be of major importance in the explanation of productivity growth. Changes in the rate of work on essentially unchanged operations, and changes in the ratio of productive to non-productive time, may be more important. This is, perhaps, particularly likely in multi-product factories, where the removal of obstructions to the flow of work is a vital element in the achievement of higher productivity. Even in B, a factory which went to great lengths in recording how direct labour spent its time, the interpretation of such changes was far from easy. For the other factories, the difficulties of analysis were more serious—and this was not just because the way in which they accounted for direct labour was less suited to the sort of analysis we wished to make.

The basic assumption involved in our measures of overall performance is that useful results can be obtained by separating out changes in productivity from changes in what was produced. At C, we concluded that useful results were obtained, and that the overall measure of performance was about right. But it is likely that this came about through a balancing out of sources of error: with the consequence that measures of particular aspects of performance could be misleading. This applied particularly strongly to aspects such as the rate of work: measures of changes the rate of work must be, in part at least, measures of what has not been accounted for by more specific changes. At D, changes in productivity and changes in what was produced were intimately connected, in that a fundamental re-organisation of production was linked to, and justified by, changes in the composition of output. Measures of overall performance based on the output produced after the re-organisation therefore differed very considerably from those based on the output produced two years earlier. The difficulties of arriving at any sensible measures of particular aspects of performance over such a period are obvious. And no matter how comprehensive the information on labour usage, any interpretation of such measures must be open to doubt when changes in performance cannot effectively be isolated from changes in what was produced.

Yet we do not wish to labour the difficulties of inter-temporal comparisons in multi-product factories. Obviously an analysis of performance in factories with a complex and changing manufacturing problem cannot be straightforward, and inadequate measures and inadequate interpretations will be better than none. We will end by making two more general points. The first is that we would have got very much less out of any inter-temporal analysis if our study had been confined to one factory. Our knowledge of how things were done, and what was happening, in two other factories was extremely helpful. At the level of detail, the discovery that some particular factor was important to the explanation of some aspect of performance in one factory would suggest a line of investigation in another. More fundamentally, in any assessment of performance what is really required is a comparison with the results of alternative courses of action: and this cannot easily be done within the framework of an individual factory. The existence of ' controls ', *i.e.* of other factories tackling similar jobs in different ways, was invaluable in suggesting what was relevant to the analysis of performance, and errors or biasses in interpretation could more easily be avoided. The full extent of our reliance on comparative information did not emerge in our studies: when one knows what is significant, it is usually possible to present the information in such a way that the appropriate points are made. We are fairly certain that the dangers of drawing wrong conclusions from the study of a single factory are serious enough to make it highly desirable to combine inter-temporal comparisons with inter-factory comparisons—or at the very least with some limited comparative information.

The second is that short-period inter-temporal comparisons are likely to give a biassed account of the pros and cons of major organisational changes. The tendency will be to lay too much stress on the improvements achieved within an essentially unchanged framework: these are the improvements which can be measured and interpreted most easily, and which will usually appear to have made the biggest contribution to improved performance over the short period. Major organisational changes are very likely to throw the measures into disarray, and to make interpretation—even when there is comparative information to draw on—difficult and doubtful. Furthermore, the working-up period of a major change is likely to be long relative to the period studied, so that it may (quite rightly in the context) appear to contribute to a worsening of performance. Often, indeed, continuity in the organisation of production is desirable: frequent interference with organisation is not a sensible recipe for increasing productivity. But in the longer run—and let it be stressed that it is quite a long run—there must come a time when something more fundamental is required: and short period inter-temporal comparisons will tend to give a very misleading impression of the advantages of such action.

OVERALL INTER-FACTORY COMPARISONS

We now come to the heart of our study—the results of the attempt to compare the productivity of direct workers in different factories. Our analysis of measures will be confined to the single half-year period of 1954 (1): the task of analysis is so complicated as to make any detailed comparisons covering a longer period impracticable. Of course, any single half-year must be uncharacteristic in many ways. Temporary phenomena such as an influx of new labour, or the birthpangs of a new design, or a new organisation, may lower productivity sharply. We know from our inter-temporal studies that productivity varied sharply from period to period for such reasons, and so we cannot reasonably expect measures relating to comparative performance in a single period to provide a fair test either of long-run performance or, therefore, of the comparative efficiency of factories in the use of direct labour. But we also know from the inter-temporal studies that there was at both B and C a considerable continuity in the way in which they solved their manufacturing problems, so that the essential features of inter-factory differences found in one period are likely to be repeated in comparisons for other periods.

Obviously this would not apply to comparisons covering D, which completely re-organised manufacture in 1954 (1). We have in fact already said almost all that can be usefully said about D's comparative productivity. Before the re-organisation, its lower productivity was pervasive. A main reason was undoubtedly a much lower rate of work, and we shall comment on this in our final section. After the re-organisation, its productivity on washing-machine motors began to rise to B's levels, but its productivity on other motors was extremely low. So let us leave D aside and concentrate on the B-C comparison.

In 1954 B and C were nearly equal in direct labour productivity. Motors were on average made faster at C; but B's output contained a lower proportion of washing-machine motors, and our usual techniques of measurement lead to the conclusion that each was rather more productive on its own output.[1] Somewhat later we shall have to consider just how reliable our comparative indicators are; but for the moment we shall just accept them. For the fine balance undoubtedly expresses neatly the real situation.

B and C had, as has already been noted, sharply distinct approaches to the manufacture of a varied output. Each approach had its particular merits. C's policy of segregating manufacturing facilities allowed certain motors in bulk demand to be made fast, while B's policy of standardising facilities allowed rather less common motors to be made nearly as quickly as the commonest motors. In consequence, C was relatively better fitted to make an output in which motors in bulk demand predominated, and B one in which there was less concentration on particular kinds of motors. And naturally enough their outputs differed correspondingly. Even over the short period 1952–4, there was, as at D, a gradual process of specialisation in market, which led to outputs being more dissimilar in composition in 1954 than they were in 1952. But it must not be deduced from this that the difference in approach arose from the differences in output. Indeed, we believe—and the analysis will bear this out—that a fundamentally similar distinction of approach would have been found even if there had been no difference in outputs. The two approaches do genuinely represent alternative —and on the evidence more or less equally successful—solutions to the problems of realising the economies of scale implicit in outputs characterised by, on the one hand, a few motors in bulk demand and by, on the other hand, a large number of different motors not very dissimilar from these.

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[1] See Table XX.

Productivity on Basic Motors

The task of comparative analysis ultimately requires one to balance the obvious advantages reaped by C from segregation of outputs and differentiation of techniques against the rather more subtle advantages of B's standardised approach. So let us begin with the comparison that shows up C to greatest advantage—a comparison of productivity on basic motors. At C such motors were assembled on a line on which output was confined to five motors of a single size and type which differed only in the details of their windings. Certain work however was done in integrated feeder sections, *e.g.* the stamping out of laminations and the diecasting of endshields. At B the corresponding motors were assembled together with all other types on the single manufacturing line, and naturally enough take longer to make.

At this point a technical note about figures is essential. All detailed analysis of direct labour usage on particular operations has to rely on cost accounting records; but, because of differences in practice that arise largely from differences in systems of wage-payments,[1] direct labour is not consistently defined in the two sets of records. The overall bias can be estimated, since reasonably comparable figures can be obtained for total direct labour usage in each factory, defined as the total time of workers whose main job is either doing or re-doing the operations of manufacture; but this definition of direct labour usage is wider than that accounted for in detail in either of the cost accounting systems. In B the labour usage that is attributed to individual motors in the cost accounts is 76½ per cent of total usage, and in C it is 85½ per cent. Later we shall be investigating this difference, which is only in part a definitional one. At this stage our concern is only with the technical deficiencies of the cost accounting records as tools for detailed comparative analysis of individual motors and operations. According to cost accounting figures, B appears to have taken 7 per cent longer than C to make a basic motor. If one were to assume that all direct labour usage not accounted for in the detailed cost accounting records could legitimately be spread *pro rata*

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[1] For a fuller discussion, see article I, p. 162 ff.

TABLE XVIII

Productivity on Basic Motors by Groups of Operations
(Total time at C=100)

Groups of operations for which:	*Number of groups*	*Time at C*	*Time at B*	*Comparative productivity of C relative to B*[1]
C far more productive	3	27.7	46.2	165
C definitely more productive ...	2	16.5	20.0	120
Not much difference	2	5.0	4.7	95
B definitely more productive ...	4	32.4	25.8	80
B much more productive ...	3	10.9	6.8	60
B far more productive ...	2	7.3	3.3	45
	16	100	106.8	107

[1] These comparisons are biassed against C because of the incomparability of the definitions of direct labour in cost accounting records at B and at C.

to individual motors, B would appear to have taken 18 per cent longer to make a basic motor: and this figure certainly gives the fairer general impression. But, since *pro rata* allocation to particular groups of operations would be even more dubious than *pro rata* allocation to particular motors, we have decided to analyse the 7 per cent difference rather than to correct all detailed figures by the same factor to achieve overall comparability. So the figures used in the basic motor comparison are loaded in B's favour—possibly by as much as 10 per cent.[1]

Table XVIII shows the results of the most detailed comparison for basic motors that can be made from the available figures. It proved possible to divide up the job of manufacture into sixteen groups which were reasonably comparable in coverage as between the factories. The dominant impression is the variability of productivity from one group to another. C's productivity on the basic motor was higher because the groups where it had a large advantage outweighed those in which B had an advantage.

In studying shafts we began our analysis of the sources of differences in productivity by measuring operational requirements by means of a rough standardised time study. We cannot proceed like this for all groups.[1] But we can begin by asking in qualitative terms how widespread and how important differences in the content of operations appear to have been. The differences were ubiquitous. For every group there existed differences either in design or in equipment or in both, of a kind that would be expected to have had definite effects on labour requirements. Moreover for twelve of the sixteen groups there is no room for doubt that the effects were large and in which factory's favour they lay. For one of the remaining groups—endshield machining and assembly—there were differences in both directions, and we could not determine which were the more important. For the other three, although there were differences of detail, those did not appear to be large enough of themselves to account for any major difference in productivity. Those three groups, together with endshield machining and assembly, constitute the row of four classified in the table as ' B definitely more productive '. The two groups constituting the row classified as ' not much difference ' turned out to be ones in which C definitely had less work to do.

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[1] Two other more trivial sources of incomparability should be mentioned—' transfer ' effects and setting by setter-operators. In the study of material usage, we found that the cost of miscellaneous materials was high at B partly because C made rather more of its minor components in the factory than did B. Unadjusted figures for direct labour productivity are therefore unfair to C; but, as for the basic motor the total transfer involved amounted to only two per cent of the total work, the additional accuracy obtained by taking it into account was not worth the trouble. An additional reason for ignoring transfer effects is that the proportion of transferred work varies from motor to motor. B makes in rather more of the small components needed for types of motor other than the basic, and the detailed adjustments for this are excessively complicated both to make and to explain—and they make no real difference to the results.

In the study of shaft manufacture labour was defined to include setters. In that context the definition was inevitable, since so much of the work done in a shaft manufacturing section is re-setting work performed by setter-operators. But for most operations setting time is far less important, and far less of it is done by setter-operators, and henceforth direct labour excludes the time of setters. However the time spent by setter-operators setting their equipment cannot be excluded—a fact which makes for some limited incomparability. Investigation allowed that the incomparability was serious only for the group of operations we have already studied—that needed to make shafts.

Of the three groups with rough similarity in the content of operations, one was highly-capitalised (pressure diecasting), one was equipped with fairly ordinary machine tools (lathes, drills, etc.) and one (general assembly) had little equipment beyond power-assisted hand tools. Thus on three dissimilar kinds of operation B appears to have had a markedly faster ' rate of work '.[2] The unadjusted cost accounting records, which overstate the real difference, suggest a difference of about 20 per cent for the diecasting and machining operations, and a difference of about 30 per cent for general assembly. When in addition, it is remembered that at B (but not at C) the rates of assembly work in 1954 were markedly below normal owing to an influx of new labour, these figures are definite evidence, not only for a generally higher rate of work at B, but also for a far sharper differential on manual operations when performed by its experienced workers.

Thus the more productive factory—for basic motors—was the one where the rate of work was lower. We came to a similar conclusion when studying shaft manufacture, although there the conclusion took the form that B's rate of labour utilisation was much the same as C's in spite of the much greater disorganisation one would anticipate from the greater variety in B's output. The broad consistency leaves no room for doubting the fact of the difference in rates of work; but this discovery is the starting-point not the end of the analysis, since the operation with a similar content in the two factories is the exception. On basic motors, at any rate, C's greater success in avoiding work substantially outweighed B's greater speed in doing it; and any analysis confined to rates of work, whether on similar or dissimilar operations, would miss the real point. So now let us examine the statistically more important groups of operations for which differences in the content of the work done were the major sources of differences in times taken.

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[1] This is by no means entirely because of the extra work involved; as important is the fact that time-studies in different factories are far from comparable. In shaft manufacture the use of fairly standard types of equipment did allow us to establish a set of standardised time-studies; but to do so for equipment and methods more particular to each factory would have been far harder, and indeed nearly impossible on operations such as coil-winding and insertion, where the methods adopted are the result of intensive development within each factory.

[2] This tendentious phrase will be used throughout to describe differences in rates of operational performance that cannot be attributed to differences in the content of operations. Obviously the average rate of work by operatives is one main element in it; but any attempt to define its precise coverage would land one in extensive and barren comparative analysis of cost accounting procedures.

C had a definite advantage in seven groups—in five, more than enough to offset its lower rates of work, and in two, just about enough. In four of these differences in design were important. In one group—the operations required to make and fix the stator shell—C's advantage was due to its choice of a different material for the shell. This difference, which had much more substantial effects on material usage, was discussed in article II, and there is nothing to add here except that it probably added some 3 per cent to B's total times. In two more groups—concerned with making and assembling minor components—C's advantages were also largely attributable to design differences, but not to any single major difference. Rather they appear to have been the result of a closer attention to the detail of design, over the many years during which C had used an essentially unchanged basic design. The same point seems also to account for the difference in another group—the operations required in stator assembly other than those of winding and inserting the coils of copper wire. In this last case there were no substantial implications for material cost; but it is important to note that in this group C's more economical design forced it to differentiate techniques as between types of motors. The simpler method used to anchor the windings in position on basic motors could not be used on all electrical types of motor, whereas B's more time-consuming method could be.

C's willingness to differentiate techniques as between motors was also important in two more groups. One, of minor importance, concerned the heat treatment used to improve the electrical qualities of the rotor, for which C used a rather simpler technique on basic motors than it did on most types, whereas B used the more complex technique on all types. The other group, coil winding and insertion, was statistically the most important of all. At B it accounted for over a quarter of total time taken, and C's advantage on this group was alone sufficient to account for all its advantage on the basic motor. At B, all windings were fitted into motors in the same way. First, coils of wire were wound on special winding machines, and then, in a very lengthy operation, one operative inserted these coils into the motor by hand. At C, only the small ' start ' coils[1] were wound and inserted in this way; the main coils were wound directly into the motor on specially-developed equipment. The latter technique was indubitably faster: C's times were 38 per cent lower than B's. But again C's adoption of this technique forced it to differentiate techniques between types of motor, as direct winding into the motor by machine could not be used for three-phase motors with their more complicated overlapping windings.

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[1] ' Start ' coils are coils which remain in circuit only for the short time needed for the motor to reach full speed.

That leaves only one group—and that a minor one—for which C's advantage was not associated either with design of differentiation of technique, and, curiously, for that one its advantage was of recent development. A basic motor comparison using data for 1952 would in the main have appeared similar; and, with the sole exception of this group, the broad classification shown in Table XVIII would have been identical. For this group however we would have found that B had a marked advantage in 1952; for in the interval B had added some extra operations in an attempt to reduce the rate of wastage.[1]

Now let us have a look at the five groups where B had a really marked advantage. Statistically, these were comparatively unimportant, accounting as they did for less than 10 per cent of the total time taken at B, as against the 44 per cent of the total time taken at C on the groups for which C had an advantage. But their study does help to identify the kinds of things at which B excelled, and indirectly contributes towards an understanding of its much more important advantage in rates of work.

For three of these groups, some part of B's advantage seemed to be associated with the use of faster, but possibly less reliable, techniques of manufacture.[2] This is not a subject easily discussed by the non-technician. If there are two ways of achieving a similar end, one quicker but probably less reliable than the other, the choice between them must always be a difficult one to make. All mass-production involves some choosing of less reliable techniques; but where exactly the line should be drawn depends on many not easily quantifiable factors—such as the quality of workmanship and the cost of putting right any faults. We saw in the study of B over time that it was tending to move towards somewhat more time-consuming and more reliable techniques in an effort to cut down waste. But an analysis of the sources of B's advantage for these groups indicates that there was still in 1954 some residual difference between the factories in this respect.

The other two groups in which B had a marked advantage raise quite different issues, which can be illustrated from the more important group—lamination stamping. This operation is by far the most capitally-intensive in motor manufacture. At B it was reckoned that the appropriate addition for overhead costs in stamping was 1,200 per cent as against a factory-wide average of 250 per cent. Consequently in both factories much effort had been devoted to the development of special devices designed to get full utilisation from the expensive presses—and the even more expensive dies—used in stamping. The presses in the two factories were rather similar—or at any rate similarly priced; but in each the job was laid out in a different way with a quite different progression of operations. These differences involved some differences in labour requirements, as they affected the number of stamping dies that descended simultaneously; but the main source of B's higher productivity was the fact that its presses were operated at least twice as fast as those at C, so that one single press operated day and night could supply all B's requirements of laminations. The technical details need not concern us; but we should note that the differences were not the result of more automatic or more expensive equipment at B, but of greater success in the detailed development of its utilisation. We stress this because up to this point all the examples have shown how C managed to simplify work by detailed development of designs and techniques. This is an example in the opposite direction, and goes to show that the difference between B and C was not one of skill in such detailed engineering work, but rather of a difference in the way each chose to deploy their limited engineering resources.

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[1] See p. 219.

[2] One of the groups is shaft manufacture, for which the cost accounting figures exaggerate B's advantage, because C made extensive use of setter-operators. The operations of shaft manufacture were studied in detail (see above, pp. 201–215) It appeared that C's advantage on the turning operations derived from the use of an automatic—and differentiated—technique for the basic motor shaft was offset partly by lower rates of work than at B, and partly by the use of more time consuming—but probably more reliable—techniques for some other operations.

This is a rather fundamental point. On balance, given the design, equipment, and methods, C's basic motor was undoubtedly much easier to make than B's. But this was largely because B deliberately chose not to differentiate its techniques for different types of motor. Where, as in lamination stamping, the operation to be done was completely standardised, B was prepared to devote more resources to achieving a quick method than C. Similarly, it was prepared to use more automatic equipment than C wherever these could be used for *all* motors. Endshields, which satisfied this condition,[1] were turned automatically at B but not at C. Shafts, which did not, were turned automatically at C but not B.

These and many other technical differences can be summed up in terms of one concept—standardisation. Both factories were much more standardised in their manufacture than was D. Each made to a single basic design, and within these designs components and the details of design were much more standardised than for D2. But within this broadly similar pattern B undoubtedly pressed detailed standardisation further, and indeed to the limit compatible with the variety in motors supplied. And in techniques too it pressed standardisation to the limit. C adopted a compromise organisation which attempted simultaneously to achieve two kinds of economies of scale—those implicit in the unity of design, and those implicit in the high demand for a few types of motor. The resulting organisation was complex: but it did permit considerable economies in the amounts of work to be done on common motors such as the basic motor, without these being offset by serious diseconomies in the amounts of work on less common motors.[2] B, by con-

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[1] Or, rather, did so when the equipment was purchased. Later market developments led to the introduction of a new type of endshield requiring operations which could not be standardised in such a way as to allow turning on the automatic machine.

[2] It should be made clear that extra costs associated with the use of more automatic machinery did not seriously offset the savings in labour times.

TABLE XIX

Overall Productivity on Coil-winding and insertion
(Time for basic motor at B=100)

Type of motor	*Proportionate importance in output at C*	*Average time taken to wind and insert coils at:*		*Comparative productivity of B relative to C*
		B	*C*	
Basic motors	51	100	62	62
Other motors with coils inserted by machine at C...	38	98	81	83
All motors with coils inserted by machine at C	89	99	70	71
All motors with coils inserted by hand at C ...	11	110	260	240
All motors in C's output ...	100	100	91	91
All motors in B's output	100	101	107	106

Note. All figures are biassed against C. See pp. 243–4.

trast, made no attempt to achieve the economies of scale implicit in high demand for a few types of motor—a decision that can be understood only in relation to the other major observed difference, that in the rates of work.

Even on the basic motors this was large, though not in 1954 large enough to offset C's economies derived from the reduction of the work to be done. In the study of D we laid emphasis on the great benefits that followed from the reduction of product variety on the fast lines. On C's fast line variety was even less than on the line for the new design at D. Yet the fastest rate of work was undoubtedly achieved in B, the factory which standardised designs and techniques, but took no steps to reduce variety by segregation or by stockpiling. At that time, moreover, B's rate of work was held down by the presence of much newly-recruited labour. The decision to push standardisation to the limit was only one of the factors contributing to a faster rate of work; but further consideration of the sources of this achievement can be postponed until we have taken a brief look at the rest of output, on which B's approach showed to greater advantage than on the basic motor.

Output as a whole—Coil-winding and insertion

C's greatest advantage on the basic motor was in the operation of coil-winding and insertion, on which its times were only 62 per cent of B's. This difference was due to C's use of specially developed equipment for winding the coils directly into the motor: such equipment was used at C for 89 per cent of motors made. The residual 11 per cent had their coils wound first on winding equipment, and then inserted by hand into the motor: the same technique as was used at B for all motors.

In Table XIX we analyse overall comparative productivity on coil-winding and insertion. At B the coils of the 'average' motor took no longer to wind and insert than did those of the basic motor. Insertion times there varied even for quite common motors, from 15 per cent below to 25 per cent above that for the basic motor, which just happened to be one the insertion of whose coils was of average difficulty.[1] At C, however, the coils of C's basic motor were definitely simpler to wind and insert than those of other types, and this partly accounted for C's much smaller advantage for the other motors which had their coils inserted by machine at C. But even on these C's advantage remained substantial; and on average over all motors in its output with machine-inserted coils, C took 29 per cent less time than B.

On motors with hand-inserted coils B's advantage was gigantic; the average time at C for such coils was 3½ times as long as for machine-inserted ones, and 2¾ times as long as for the coils for equivalent motors at B. As a result, even on C's own output, and neglecting all costs associated with the equipment itself, two-thirds of C's apparent savings in labour time from machine-insertion were swept away. And on B's output—given the usual assumptions—B would actually have appeared the more productive.[2]

In the study of B over time, we discussed the coil insertion operation in some detail; for it was the one manual operation on which target times had been reduced particularly sharply—by 40 per cent in two years. Although this target was not achieved on average, it was in fact easily achieved by the experienced workers. Indeed so fast did they work that they could do the job by hand nearly as fast as it was done by machine in C. This remarkable achievement is a sign of what can be done by detailed attention to every movement in an operation. B's work-study section devoted a great deal of effort to this particular operation, and suggested many improvements. This kind of lengthy and difficult manual operation offers work-study the greatest opportunities for discovering ways of simplifying and streamlining the job. Moreover it is one in which every individual has to be left to find his own pace; and so is one in which experience, quality of effort, and ' productivity-mindedness ' on the part of the operative, are likely to pay off best.

So hand-insertion of coils is an operation for which one might expect to find a larger than average differential between work-rates at B and at C. Indeed it is quite likely that, given the kind of factory each was, each had decided correctly for or against mechanisation of coil insertion,[3] and moreover that each decision would rightly have stood if either had been called on to make the other's output. But one thing is quite certain. If C had opted for hand-insertion for all motors, it would have been much faster at this job. One reason for this is that at C the rate of work tended to be low on the special line, where most but not all hand-insertion was done; and any extension of hand-insertion to lines with less varied outputs would tend automatically to raise the average rate of work. But the more important reason is simply that more attention would have been devoted to the task of raising the rate of work on this operation.

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[1] A similar result would not have been found had B been making to C's design, since the detailed arrangement of coils was different at C.

[2] There is a bias in these figures against C arising from differing definitions of direct labour, which on average all over operations and motors amounted to some 10 per cent. See above, pp. 243–4.

[3] This remark applies only to the kind of machine that C was using in 1954.

The example of coil-winding and insertion is an extreme one; but it does bring out the main danger of a decision to differentiate techniques—that the level of productivity on the less mechanised technique will be far lower than can be accounted for by the difference in technique alone. Because it is used on only a small part of output, and because the output on which it is used is likely to be rather a mixed one, there is less inducement to devote recources to the task of achieving a high rate of work. This is also the main danger of segregation even when it is not associated with differentiation of technique. Of this we have already had one illustration in the low rate of work on the night shift for the manufacture of special shafts at B, which used the same equipment as was used during the day to make the commoner shafts. But since only a small proportion of motors had their coils inserted by hand at C, and comparatively few shafts were produced by the night shift at B, neither of these examples is directly relevant to the main form of segregation at C—the division of assembly work and much machining work into several separate lines. Our next example, general assembly, is.

Output as a whole—General Assembly

There were three assembly lines in the old building at C.[1] In relation to the fastest of these, where only motors requiring the same assembly work as the basic motors were assembled, B appeared to have a productivity advantage of about 30 per cent on the general assembly operation. In relation to the other main assembly line, where a limited variety of about 80 motors was made, the differential appears to have been around 40 per cent. And in relation to the assembly section for special motors B's advantage appears to have been much as 65 per cent. Combining these figures we find an average advantage for B of 37 per cent on C's output; and of some 40 per cent on B's output. The difference between these two figures is trivial; evidently B had a really marked advantage on this group of operations.

The obvious procedure would be to submit the figures to detailed analysis, in order to discover why C's disadvantage was much greater on some types of motors than on others. We did this, and found a large number of specific reasons for differences in assembly times at C, many of which would not affect times at B, where design was more standardised. But one important source of the differences at C made us doubt the value of this sort of analysis. At C allowed times (i.e. the times implicit in the piecework prices set) were lower for common sizes of motor than for less common ones even though very similar assembly work was required. The effect of this differential was to raise the average piecework price per motor assembled on the second line above that on the first, and to raise that on the special line even more. Samples of average piecework earnings per hour suggested that as between the two main lines the piecework prices were fair,[1] in that they enabled similar grades of labour to achieve much the same earnings per hour. So undoubtedly similar work was done more slowly on the second line; but the further deduction suggested by the detailed analysis that most of the extra time was attributable to the uncommon sizes cannot be fully accepted. The setting of higher piecework prices for assembling these has to be seen as a simple means of compensating workers on the second and special lines for the likely effects of the disorganisation associated with variety in output on average rates of work.

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[1] No comparisons between B and the new line at C will be attempted. For a discussion of that line, see pp. 227–9.

This illustrates a major difficulty in the interpretation of detailed comparisons. The temptation is to attribute to *specific* differences between motors extra times which are really attributable to the effects of variety itself. The temptation is particularly strong when the specific differences do in fact make a substantial difference to the work that has to be done. If techniques or designs are differentiated, then obviously different piecework prices have to be set. Any compensations for the effects of variety are likely to be concentrated on those techniques or designs which are peculiar to lines producing a more varied output. It is only too easy to attribute entirely to the differences in designs or techniques differences which are partly a consequence of the segregation of facilities, and so exaggerate the importance of specific technical factors. Segregation is often accompanied by some differentiation of designs of techniques; but its primary purpose is usually to separate the less varied from the more varied output. The more varied output will be made more slowly because it is varied, and not just because techniques or designs may increase the work to be done.

For general assembly the detailed analysis implied that more work had to be done on the slower lines at C. But it is likely that the inter-line productivity differentials were mainly attributable to the greater variety on the slower lines, and that they therefore give an impression—though probably a somewhat exaggerated impression—of the effects of segregation on work rates in that factory. Work rates at B, however, seems to have been much less affected by variety. Whereas at C motors on the two main lines were assembled in large batches for stock or to meet bulk orders, at B there was no attempt to batch assembly work. Every day at B motors of all kinds were assembled in numbers ranging from 1 to 500, with the result that the daily variety of assembly work on B's line was far higher than on C's special line. B's considerable productivity advantage—even in relation to C's fastest and least varied line—suggests not only that rates of work were higher there, but also that they were comparatively little affected by the variety in the work to be done. This conclusion was borne out by the detailed study of coil insertion at B, which showed that average times for particular motors were independent of the numbers produced. Even at B, however, variety must be expected to have rather greater effects for operations where there are such specific sources of disorganisation as the need to re-set equipment.

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[1] The special line had a lower level of earnings per hour, but that was largely due to its use as a training section.

TABLE XX

Comparative Measures of Overall Productivity: B and C

(*Time taken per motor at C to make own output=100*)

	Time that was, or would have been, taken per motor to make an output equivalent in composition to:	
	C's output	*B's output*
At C	100	110
At B	107	109
Productivity of C relative to B ...	107[1]	99[1]

[1] These figures are not adjusted for 'transfer effects', *i.e.* for work done in one factory but left to a supplier in the other, or for differences in the amount of setting work done by operatives. Neither adjustment would be large. B's times were also higher because it used a different material for the outer frame of its motor. If one were to exclude these operations from the comparison, and to adjust for transfer effects, productivities of C relative to B would have been around 105 and 96 (± 2–3 per cent).

The different effect of variety on work rates at B and C is crucial. If we can explain why this was so, we can really begin to understand why these two adopted such organisationally different solutions to the problems of manufacturing a varied output. At one level the explanation is simple enough; the more that labour was on top of its job, the less it was likely to be troubled by variations in its detail. And in this sense it is reasonable to regard the two facets of B's success in general assembly—a high rate of work, and a high adaptability—as being evidence of some essential difference in the quality of the effort applied.

Organisation, Variety and Work-rates

We shall confine ourselves to these two examples of the results of overall comparison for particular operations; for they suffice to illustrate the main contrasts between B and C, and thus allow us to draw up some kind of balance sheet of the advantages and disadvantages of their very different approaches. This is not easy in view of the differences between their outputs. B's organisation would be suitable to almost any output confined to motors of a single basic design which differ between themselves only in detail. This assertion is borne out by the comparisons for output as a whole shown in Table XX: the measures suggest that B would have taken just about as long per motor to make an output of C's composition as it took on its own output. Comparing B and C on the basis of an output of C's composition, C was decidedly the more productive in 1954. The measured difference was 7 per cent: if allowance were made, as it should be made, for transfer effects, C's productivity would have been 8–9 per cent higher. Of this, some 3 per cent was to be attributed to the major difference in material chosen for the stator shell.[1] C's output was one in which basic and other washing-machine motors predominated, and one in which therefore the advantages of differentiating

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[1] See Article II, pp. 113–4.

TABLE XXI

Various Outputs Analysed according to Place of Manufacture at C

	Motors normally assembled on:				
	First line	*Second line*			*Special line*
		Standards	*Other*	*Sum*	
C's output:					
Number of different motors in 1954 (1)	*5*	*72*	*6*	*78*	*?*
Percentage of total output					
in 1952 (1)	47	32	7	39	14
in 1952 (2)	40	31	12	43	16
in 1954 (1)	48	17	22	39	13
B's output:					
Percentage of total output in 1954 (1) ...	31	29	13	42	27

Note. In computing this table we have shown how output would have been allocated before the new line at C began working.

techniques in favour of the rapid manufacture of such motors were greater than they would have been if C had been called on to make B's output.

However, this predominance of washing-machine motor demand was not the precondition for C's approach that it was for D's. For the basic principle in C's approach was not differentiation in favour of washing-machine motors, but differentiation against the special. Manual coil-insertion was restricted to 11 per cent of motors, special assembly to 16 per cent, and in most machining departments the proportion of work done in special sections was even lower. Such an approach could be applied to any output in which for most components a relatively small number of variants accounted for the bulk of output. Indeed in some ways C's approach might appear not inappropriate to an output of B's composition.

In Table XXI we compare the structure of the two outputs, according to the line on which they would have been assembled at C.[1] The outputs were obviously very different. In 1954 (1), the five very similar motors—they differed only in the details of their stator windings—which were the only motors assembled on the first line, were 17 per cent more important in C's output, and special motors were 14 per cent less important. And the figures for earlier periods (particularly those for the slump period 1952 (2)) show that this difference in output structure was not a recent development. What however had been changing quickly at C—it was part of the tendency towards polarisation in output referred to earlier—was the structure of output on the second main manufacturing line. In 1952 (1) standard motors, *i.e.* motors made for stock and not to order, were more than four times as important as other motors, *i.e.* special motors, the scale of demand for each of which was sufficient to justify manufacture on a main line. By 1954 (1) the latter exceeded the former, and this development in demand had somewhat diminished the role of the policy of making standard motors and standard components for stock in ensuring the long runs required to obtain economies of scale. For B's output, in which standard motors were still relatively numerous, this role would have been more important.

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[1] In this analysis we ignore the new line at C entirely.

So it seems reasonable to ask how successful a C approach would have been with a B output. But the Table also brings out quite clearly that very substantial changes, particularly in the allocation of motors between lines, would have been required at C to make such an output. It could have been done; there was nothing very special about most specials. The usual special incorporated a few minor variations from a similar standard motor, and its assembly on one of the main lines would have been quite feasible from the technical side. But our measures are based on the assumption that such re-allocations would not occur. In the study of changes over time at C, we concluded that measures based on this assumption were about right; but only because (a) major reallocations had not been essential and (b) no reallocation of importance had been carried out. Since C would have had to reallocate motors between lines to make B's output, we have no really relevant quantitative information that would permit a measure of how things might have turned out on a C approach to a B output, even though that approach seems in principle well-suited to such an output.

It is therefore not surprising to find that the comparative measures turn out on analysis to be seriously misleading in detail. It is not difficult to show that our measures tend to exaggerate the degree of specialisation to a particular structure of output that is involved in the differentiation of techniques.[1] We have argued, for example, that if C had been faced with the need to do more coil insertion by hand, it would have been able to speed up this operation. Our measures will, therefore, exaggerate the comparative unsuitability of C's differentiated techniques for a B output. But in the overall measures this tendency towards exaggeration for the particular groups of operations where techniques were differentiated is compensated by an opposite tendency for other groups. If we were to take the detailed measures at their face value, we would be led to the conclusion that—outside general assembly—C derived no significant advantages from segregation except where it was associated with major differentiation in techniques. And from this it would follow that at C variety in operations had little or no direct effects on work-rates, in flat contradiction of the lengths to which C went to eliminate such variation.

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[1] The operations of endshield machining provide an extreme example. In 1954 a particular type of motor was relatively uncommon. In C therefore the machining of endshields for this type was pushed off the main manufacturing lines, and such endshields took 75 per cent longer to make than those for the basic motor. The use of this relative to estimate how long C would have taken to make endshields for B's output, in which such endshields were proportionately eleven times as common, leads to an estimate that average times per endshield would have been 9 per cent longer than on C's own output. But in 1952 this particular type of motor was much commoner at C, and its endshields were then machined on the main lines at an average time only 25 per cent longer than those for the basic motor. Use of the 1952 relative leads to the conclusion that C could have taken 3 per cent less time to make endshields for B's 1954 output than for its own 1954 output. Thus the specialisation implied by the 1954 relative is quite bogus, since the only reason why the relatives had changed was an easily reversible reaction to the declining demand for a particular type of motor.

From which we conclude that if the overall measures give any accurate impression of how suitable a C approach would have been to a B ouput, it would only be because the exaggeration of the advantages of segregation when accompanied by differentiation was compensated by an under-estimate of its advantages when not so accompanied.

For these reasons we cannot attach much importance to the result, shown in Table XX, of our calculation of the comparative productivity of B and C in making an output of B's composition. The measure implies that on such an output B would have had a slightly higher productivity than C. Certainly the measure is correct in suggesting that the C's approach would be more difficult to apply as successfully to an output like B's as to its own output; but more than that cannot be claimed for it. But even though the overall measure is not in itself particularly useful, an analysis of detailed measures—which are of themselves liable to be very misleading—is useful in identifying qualitatively the advantages and disadvantages of the two approaches.

The main advantage of C's approach came out clearly enough both in the basic motor comparison and in the shaft manufacture comparison. It was the saving in operational requirements made possible by differentiation of techniques—and, to a lesser extent, of design. Two of its main disadvantages have also come out at various stages. One is a lesser flexibility in what can easily be made. How important this is must depend on the market; but the inter-temporal study did not suggest that it had been very important. The second disadvantage is the comparative neglect of the special components and motors. Much more effort will be put into improving the way in which work is done on motors or components in bulk production than can sensibly be put into improving the manufacture of specials in segregated sections. The effect of this comparative neglect of a small proportion of output can be quite substantial (as it was, for example, in coil-winding and insertion); but of itself is unlikely to offset the advantages of segregation when segregation can be accompanied by major differentiation of techniques. Clearly the balance depends on the relative importance of special and non-special motors; and with an output composed as C's—or even as B's—the proportion of work done slowly in special sections can on average be kept low enough to enable the economies in the faster sections to predominate.

The third much less easily assessable disadvantage of C's approach is complexity in manufacturing organisation. B's approach had a simplicity that derived from the reduction in the number of things that had to be decided. The engineering departments—including the work-study section—could concentrate on a single way of doing any particular operation. The production control staff did not have to decide where motors or components had to be made, but only when—and even that was easier, as the standardisation of designs and methods made work speeds at B much less sensitive to the order of manufacture. At C there was no such simplicity. Decisions had to be taken about where particular motors and their components were to be made. If manufacture of motors and components was for stock—and stockholding was crucial to C's approach on the main lines—somebody had to decide what level of stocks should be held of each motor and component, and on what scale each should be re-ordered. All this required a considerable office staff, even if, as in C, the job was routinised so that most of the decisions were taken by clerical staff guided by automatic rules. The more varied and the more special the output the greater the difficulties in the routinisation of planning procedures. It is fairly safe to arrange the manufacture of standard motors and components according to set rules laying down appropriate stock levels and re-order sizes, but to do so for any special motor or component required for a single customer has obvious dangers. Indeed it is rather difficult to assess how C's procedures would have worked in practice if such a large part of output had not been of one type of motor only.

This staff costs money, as does the extra inventory involved in holding stocks of components; but the effects on direct labour productivity are likely to be more important. First, there is the danger that the system is slow to respond to change in the structure of output. In practice output may not be allocated to particular facilities in quite the best way, so that all the theoretical advantage of segregation cannot in fact be realised. But second, and much more important, is the likely effect on the flows of work. Segregation, batching and stockpiling all helped to limit the disruptions associated with the production of a varied output, by substantially reducing the frequency with which operatives and machines had to change over from one operation to another. So too did C's comparative generosity in the provision of equipment, which reduced the amount of idle labour time associated with machinery being out of action for resetting. There is something to be said for a generous attitude to stocks and to the provision of equipment even on a single-product line, as variety in required operations is by no means the only source of disorganisation. Machine breakdowns, faulty work, varying work-speeds by operatives, varying cycle-times of successive operations, all make it advantageous that operatives should have work on hand, and so be to some extent insulated from any disorganisation elsewhere on the production line. But such gains have to be offset against the loss of factory flow. If, as in C, the work of one operative, or of one section, is rendered fairly independent of that previous operatives or of other sections, then there must be some diminution in the sense of urgency about getting any particular job done, and thus some reduction in the pressure on the personnel on the floor—supervisory as well as operative—for improved performance. Nor is this just a matter of speed in work. On a flow line attention is bound to be concentrated on anything which holds up the flow of work, and it could be that the spotlight so thrown on sources of disorganisation is the first step to their effective elimination. One of the drawbacks of too complicated an organisation is the loss of control that may come from the greater difficulty of identifying the real sources of trouble.

At B the desire to create a sense of urgency about the performance of work was the main reason for the organisation it adopted. It also lay behind its design decisions. To maintain a flow line does not require complete standardisation of the work to be done. Good workers should be able to take variations of detail in their stride. But it does demand the elimination as far as practicable of variations in the content of operations between different motors which substantially alter the length of operations or which require the resetting of equipment; for these cannot but cause some disruption to the flow. At C the most valuable type of standardisation was to use the same component in different motors, as this would raise the scale of manufacture of that component; but at B it mattered as much that different components—particularly machined components—should have as much in common as possible[1]—which is one reason why it is so difficult to say anything concrete about the advantages of standardisation.

In its direct purpose of speeding work B's organisation was effective. Wherever there was any similarity in the operations to be done, work was done at B much faster than at C—even when the contrast was between a line at B with a varied output and one at C without variation. But the impression given by earlier figures of the size of this differential requires some qualification, concerning what in the inter-temporal studies we called ' non-productive ' time. This was defined as the time of direct workers that was not attributed to individual motors or operations in a factory's cost accounting system. For reasons given in Article I, figures for ' non-productive ' time from different factories are, mainly because systems of payments differed, inconsistent in definition[2]—but not to an extent that would explain the apparent differences (see Table XXII). At B, in 1954, there were, for every 100 ' productive ' hours, 30½ non-productive hours. At C the corresponding figure was 14½ hours. One major source of difference appears to have been idle time of one kind or another, and its high level in B's machine shop shows that disorganisation associated with re-setting was—in spite of a sharp improvement between 1952 and 1954—still of substantial importance, although not of sufficient size to offset B's higher rates of work (about 20 per cent) on machining operations. The other major source was faulty work, which required three times as long to put right at B as at C. Although these figures undoubtedly exaggerate the real difference, details from testing returns confirm that there was a major difference in test failure rates at the two factories.

At B 32 per cent of all motors presented for final test failed to pass first time. At C the failure rate was 12 per cent. Nearly all failed motors later passed the test with only a small amount of further work, and scrapping amounted to only 2–3 per cent. One possible interpretation of the testing figures would be that higher speeds of work at B led to more human errors there; but detailed investigation shows that the explanation was not as simple as that. Over half the motors rejected at B were failed on grounds of excessive noise as measured by a special machine. At C rejection for this reason was

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[1] *Cf.* p. 203, footnote.

[2] See article I, p. 163–4.

TABLE XXII

'Non-Productive' Time of Direct Workers: B and C

	At B:			*At C:*
	in general machine shop	*in assembly department*	*in all departments*	*in all departments*
'Productive' time as deduced from cost accounting records	100	100	100	100
'Non-productive' time associated with waste[1]	4½	20½	16½	5½
Idle time[2]	8½	5½	7	1
All other[3]	4½	7½	7	8½
Total time	117½	133½	130½	114½

Note. The figures in this table, particularly those relating to idle time, are far from comparable in definition, as B took much more trouble to charge out non-productive time to other accounts.

[1] *I.e.* any time spent on work subsequently scrapped, or any time recorded as spent on making good faulty work.

[2] *I.e.* any time spent waiting for work for any reason. This item includes any conventional allowances made for expected idle time, including that made to some workers for cleaning their own machines.

[3] Includes time spent making spares or doing repair work not done in special repair sections, time spent adding to work-in-progress, training time not included in direct labour time, and one or two other items. It may also include small sampling errors.

negligible; but the test was by ear. Earlier experiments at C with a machine for testing noise had been abandoned on the grounds that it gave unsatisfactory results! So it is difficult to know what to make of such a difference. The obvious questions—' Was B's motor noisier because of its design, or because of the quality of workmanship suffered from the high rate of work, or because at certain points faster or possibly less reliable techniques had been chosen? '—are clearly important. So in a different way are the questions ' Was B's motor as supplied a better motor, because of more rigorous testing standards, and, if so, how important was that to the customer? '. The difference was staggeringly large, and it is most unsatisfactory not to be able to do more than list possible relevant factors.

The second point to note about the testing figures is the variation between lines at C. B's failure rate—after eliminating failures on grounds of noise—was the same as on C's second line, and much higher than on either of C's other lines. Moreover we have been told that at C failures on the second lines were usually more serious—in the sense of the quantity of rectification work needed—than those on other lines. It may be that this in part stemmed from the attempt made on that line to combine some variety in output with a fairly high rate of work—and this might suggest that it was not so much a fast rate of work as such at B, but its combination with variety in output that lay behind the higher failure rate there. If so one major advantage of preference for mechanical and organisational solutions to the problem of variety would be that it reduced the scope for human error.

The higher proportion of re-operation at B came nowhere near to offsetting its higher rates of work. What did so was the insistence on making every motor in the same way, instead of being ready, as was C, to vary the techniques according to the scale of demand for the particular component. This did bring a substantial economy in equipment. B's output was at this time somewhat over half C's, yet it had only one manufacturing line worked largely on a single-shift system. C had three *plus* a new one coming into operation, of which one was worked entirely on the double-shift system, and another was worked half on this system. Yet the amount of equipment on B's single line was not much greater than that on any of C's lines. In part, this may have been because B was short of space; the packing of machinery was much tighter there. But nevertheless we are fairly certain that this aspect was incidental and that, given the space, B would still have chosen as it did, because it would conflict with its principles to supply more machinery than was strictly necessary.

This was much more than a matter of saving on depreciation charges—remarkable as those savings were in a case like shafts.[1] It was also more than a matter of simply reducing the number of things to be thought about —and thus, as in lamination stamping and coil insertion, giving a better chance of concentrating effort on improving the way in which operations were done. For it all links up with the ideas held at B as to how best, not only to get work done, but also to get it increasingly well done. The elaborate system of targets for each operation, with monthly comparison of actual rates with target rates and annual revision of targets, was all part of a system under which steady and effective pressure on performance was exerted. And our brief survey covering 1952–4 suggested that it did allow targets to be tightened each year, with a reasonable prospect that they would be achieved in normal circumstances. In terms of comparative rates of work, the results are impressive; but our comparison suggests that in terms of direct labour productivity much the same results could be achieved elsewhere by other means. In a multi-product industry the cost—in extra work to be done—of the standardisation involved offset the gain from a whole-hearted concentration on the problem of raising work rates.

Productivity and Pay

So far we have confined comparative measurements to rates of output per hour of work, regardless of the type of labour, the time of work, or the rate of pay. As a result we have given a one-sided picture of the economy with which these factories employ direct labour, and we want now to consider alternative measures of performance.

The most important of these is the direct labour cost of output. According to measures in terms of output per hour, D was far less productive than either B or C; but the figures in Table XXIII show that nevertheless, in terms of direct cost, it was as economical as B—at least if the comparison be confined to the designs of similar size—because it paid 38 per cent less per hour for its direct labour. The change to assessment by cost also alters the com-

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[1] See Table VI.

TABLE XXIII
Productivity and Pay
($B=100$)

	C	D	
		restricted[2]	*all equivalent*[3]
Average direct labour cost per hour worked[1]	88	62	
Motors made per hour worked	109	72	67
Motors made per penny of direct labour cost	124	116	101
Equivalent output per hour worked (range)	99—107	54—65	50—59
Equivalent output per penny of direct labour cost (range)	112—121	87—105	81—95

[1] Including employers' national insurance contributions but excluding welfare expenditure (see Table XXIV).

[2] Comparisons confined to motors of designs D1 and D2.

[3] Comparisons including any motors of designs D3 and D4 with equivalents at B.

parative B-C picture. The rough equality in equivalent outputs per hour corresponded to a marked advantage to C in terms of direct labour costs on equivalent outputs, as C's direct labour was about 12 per cent cheaper per hour worked than B's. And so by the test of manufacturing performance that would appear most directly relevant to market success, a high productivity does not appear to have been necessarily advantageous. The cheapest manufacturer—in terms of the cost of direct labour and not necessarily of course in terms of total costs—was one of the two more physically productive. But the other productive factory, and the one which was more productive because its workers achieved the highest rates of work, had no marked cost advantage over a factory with a 40 per cent lower productivity.

Our purpose in this section is to try to elucidate the nature of the relationship between productivity or pay. We begin by examining one easily isolable element of labour costs—the costs of differences in the timing of work. Premium payments for shift and overtime working are made in all three factories, and the extent of such working also affects the proportionate importance of certain other costs: for instance, other things being equal, overtime reduces the cost per hour of work of national insurance contributions, while shift-work raises it. So in Table XXIV we show all types of cost and not just the premium payments. Base pay means weekly payments less premium payments for overtime and shift working but including any other types of bonus, and it will be seen from the Table that contributions to pay differentials between the factories deriving from premium payments was of a minor nature. C's decision to work the double-day shift in most departments did raise its labour costs relative to D's, but not by very much. More surprisingly it did not to do so relative to B's, a fact only partly accounted for by the heavy working of overtime in B.

For this there was a special explanation, not of any very great importance to this enquiry, but one which is nevertheless worth a minor digression. At D, which paid its workers by the hour, a phrase such as 'time-and-a-half'

TABLE XXIV

Direct Labour Costs

	Composition of labour costs, total direct labour cost = 100		
	B	*C*	*D*
Base-pay	87	88	89½
Premium payments:			
for shiftwork[1]	—	3	—
for overtime	4½	2	3
Holiday pay	6	4½	5½
Employer's National Insurance contributions	2½	2½	2
Total direct labour cost	100	100	100
Loss on canteen and other identifiable welfare expenditure[2]	3½	½	1
	Comparative Costs per Hour (B = 100)		
Base-pay[3]	100	89	64
Total direct labour cost	100	88	62
Total direct labour cost *plus* welfare expenditures	100	85	61

[1] At B shift premium payments are not separately distinguished. As shift-working was restricted to very few manufacturing sections, the proportion is unlikely to have been over 1 per cent.

[2] Allocated to direct labour *pro rata* to its share in the total cost of wage and salary-earning labour.

[3] Including at B, but not at C, shift premium payments.

used to describe the rate of pay for overtime on Saturday meant what it said. A worker did receive 50 per cent more for work on Saturday than he would have for work within the normal working-week. But at C, where nearly all direct workers were paid by the piece, it did not; premium payments there were based on time-rates, with the effect that the phrase 'time-and-a-half' meant that the worker received on average only about a third more than he would have for normal day-work. Thus overtime and shift-work were, relative to ordinary day-work, cheaper at C than they would have been at D. For instance, the national agreements for the engineering industry laid down that on the double-day shift the normal working-week shall consist of five 7½ hour shifts, but that the worker shall be paid for 44 hours. At D this would mean that shiftwork would have been 17 per cent more expensive per hour than daywork, as the employer would have borne the whole cost of the working-time lost by each worker through the introduction of shift-working. But for C, where the unworked 6½ hours were paid for at time-rates, the effective extra cost over ordinary day work was on average only 12 per cent, and one might say that, as a result, some of the cost of the lost time was borne by the worker. So it was cheaper for C to go over to shift-work than it would have been for either B or D. We do not in fact believe that this was the main reason for C's decision to work shifts; but it is not difficult to imagine circumstances in which such a difference in the proportionate cost of shift-work could swing the balance. And it is perhaps instructive to consider the implications of the comment that in a certain sense C can be described as

TABLE XXV

The Composition of the Direct Labour Force
(percentages of male employees)

	At B	*At C*	*At D*
In machining sections	66	78[1]	38
In other sections	26	17	10
In all sections	36	49	19

[1] Of which 5 per cent boys (under 21). The percentages of boys employed elsewhere were very low, as were the percentages of girls (under 18) everywhere.

' efficient in the use of labour ' because it adopted a system of payment under which the workers bore part of the cost of shift-working.

But, as we said earlier, timing differences in work have only minor effects on comparative levels of pay, and we want now to go on to discuss the more important question of why base-pay per hour is so different in each factory. Let us begin by dismissing one possible explanation—regional variations in the level of pay. We collected no special information on this point; but we can say that none of these factories was located in any area—such as the West Midlands—in which wage levels are well-known to be high. We cannot say that there were no differences in pay as a result of each factory's location; but we can say that location cannot account for any major pay differentials. The major explanation for the observed pay differentials has to be found in the factories themselves.

For D's position there are two obvious explanations. The first is its decision to employ a very high proportion of women. Table XXV shows that at C one-half of all direct workers were male, and at B over a third; but at D less than one in five. Further investigation shows that in this respect B's and C's employment policies were even less different than the figures would suggest—at any rate, neither policy can be described as one of consistently employing a more expensive grade of labour. But D undoubtedly did employ a cheaper grade of labour as a matter of policy. The second is that D, unlike the other two factories, did not operate any incentive scheme linking pay directly with output. Discussion of D's decisions is best postponed until we have compared the two factories which in these important respects had much the same policy.

We have no doubt that in both B and C the incentive schemes were effective in their contexts, and that they were extremely important in the achievement of the productivity that was achieved. C's scheme was a straightforward piecework scheme under which part of a workers' pay was proportional to his own output (or to that of a small group) of which he was a member). Under C's organisation, the individual worker—particularly on machining work—had considerably more freedom to set his own pace of work than in B. This is a form of organisation peculiarly suited to an incentive scheme in which there is a simple relationship between individual output and individual pay. The relative absence of pressure stemming from the flow of work makes it more essential to provide a financial spur to effort (and also to make idle time unattractive); and an individual incentive scheme is more likely to be fair in these circumstances than it would be in circumstances where the output of one worker is more closely dependent on the output of others. We do not say these are sufficient conditions, but we do say that in C the scheme does seem to have been reasonably successful on the old lines, partly because of a spirit of give and take between management and men.

B's incentive schemes were much more complicated. First, there was a scheme of direct bonus payments analogous to C's piecework scheme, but with a number of substantial modifications in the worker's favour. The scheme was somewhat more progressive—particularly for women.[1] The minimum payments were more generous. Special provisions were made to pay bonuses when output fell for reasons outside the workers' control. Special concessionary bonus rates were granted to inexperienced workers. In fact, elaborate precautions were taken to make the scheme as fair as any such direct bonus scheme can be. Second, there was a scheme of factory bonuses, paid to all employees, worked out on the basis of the relationship between actual performance and target performance in the previous month. In 1954, this second bonus was not very high, because performance was well below target; but in later years it grew substantially in importance, until it was at least as important as the direct bonus scheme.

The combined effect of these two schemes at B was to pass on to the direct workers all or more than the savings in direct labour cost due to higher work-rates. But we shall misunderstand this incentive scheme if we think of it as just a spur to harder work. In a factory like B, where all the work was put down on a single line, only a major co-operative effort is likely to be successful in ironing out the difficulties that stand in the way of a steady flow of work. One purpose of this factory bonus scheme was to emphasise the co-operative effort needed. But a second purpose was perhaps as important—the emphasis thereby laid on the target, as something to be achieved rather than a pious hope. Actually in 1954 (1), for reasons given at length earlier, the target was nowhere near achieved; but one cannot understand B's approach unless one emphasises that this failure was seen as an abnormal event, and that the fulfilment of the targets was regarded as a pre-condition of efficient working. An illustration of this emphasis laid on the fulfilment of targets and plans is the fact that at B weekly output always equalled the planned output, both in numbers and in composition. If necessary overtime was worked to make up for shortfalls in productivity; but the floor always produced what it was told to produce, since this was essential to the smooth working of the factory.

A high-quality and co-operative labour force was essential to this approach, and all B's personnel and wages policies were directed to obtaining such a labour force. To isolate the effects of any one element in policies would be impossible. We have no idea to what extent B's faster rates should be put

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[1] Because the sex differential at C was confined to piecework payments, men on average received two-thirds and women only a half of the savings from any increases in rate of work.

Table XXVI

Comparative Productivity per Equivalent Hour

(B=100)

	C	D[1]
Average pay per hour	88	62
Equivalent hours per hour[2]	101	91
Average pay per equivalent hour[3]	87	68
Equivalent outputs per hour	99—107	54—65
Equivalent outputs per equivalent hour	98—106	59—71
Equivalent outputs per penny of labour cost ...	112—121	87—105

[1] For motors of designs D1 and D2 only (see Table XXIII).

[2] An equivalent hour is an hour of male adult semi-skilled work, or that number of hours of work by other grades which could on average be purchased at C for the same cost. For instance, 1.45 hours of actual work by women are counted as equal to one equivalent hour. In B the ratio of equivalent hours to hours actually worked is .81, and the figures in the table express the relation of the corresponding ratio at C (.82) and at D (.74) to this ratio.

[3] *I.e.* the best estimate of the average differential in pay per hour between workers of similar grades in different factories.

down to its creaming the labour market more than C. Undoubtedly it did, for it had a larger personnel section which took rather more care in selecting labour from the available applicants. (Neither B nor C appeared to have difficulty in getting as many applicants as it wanted, as both paid above local averages). We have no idea how important B's more intensive and longer training was in improving the quality of its labour. And, finally, we have no idea how important was the particular system of very generous incentives it adopted: it was believed at B that the incentive scheme was increasingly effective, as the workers accustomed themselves to the possibilities of increasing pay. But we are fairly certain that it was a necessary condition of B's approach to its labour that most of the benefits from direct labour saving—as opposed to consequential ones in overheads—should accrue, and be seen to accrue, to the workers. This may be the recipe for achieving a high and rapidly rising rate of work. But if so it is one with considerable financial disadvantages to the employer. One of the financial advantages of avoiding work is that fewer of the gains have to be shared with the workers.

And now let us consider D's labour policy. We begin by making the simple point that D's average rates of pay were not lower just because it employed a higher proportion of women. In the two factories where sex differentials in pay could be measured, women's pay per hour was on average a little over two-thirds that of semi-skilled men. This consistency permits one to define a measure of labour usage in terms of equivalent hours, where an equivalent hour is defined to be either an hour of male adult semi-skilled work or that amount of hours of work of any other grade (women, boys, apprentice-trained skilled) which could on average be purchased for the same cost *in the same factory*. On a basis of equivalent hours D's comparative productivity was still much lower than that in any other factory, and the figures in Table XXVI leave no doubt that both men and women were paid much less at D than either at B or C. Of the total average pay differential of 38 per cent between B and D, as much as 32 per cent seems to have been between workers of the same grades.

We think there are good reasons for associating D's lower levels of pay with its employment policy. In both C and D the differential in average earnings per hour between men and women was wider than that laid down in national agreements on minimum rates. In each actual average hourly earnings were for both sexes well above these minimum rates; but, because both sexes were in each factory paid according to the same system, the actual average differential could not be all that much wider than the differential in minimum rates. And in D the difficulties in recruiting men suggest that the actual differential was not wide enough. A general level of factory pay adequate to attract and retain enough female employees was not sufficient to attract and retain enough male employees. We feel fairly certain that had D not been so largely staffed by women, problems of labour supply would have forced a raising of the general level of factory pay, though not of course necessarily to the levels prevailing in the other factories.

Probable effects on average rates of work are much less easy to assess. Again let us begin by making a simple negative point, namely that D's rates of work were not lower just because it employed women on certain operations where the others employed men. Possibly the highest rates of work achieved at D relative to those elsewhere was on the machining of motors of the new design D1. At D the work was nearly all done by women, while B and at C the corresponding work was done partly by women and partly by men. But a general check, section by section, leaves no doubt that productivity in D compared as unfavourably with that in B or in C where it employed workers of the same sex as where it employed women and they employed men.

This negative point is easy enough to make; but it is less easy to make useful positive points about the effects on productivity of D's decisions to employ a high proportion of women, and to do without a direct incentive scheme. All we really know is that D was a factory with low productivity. One aspect of the productivity increases achieved at D seems suggestive. It was in D—as it did not appear to be in B and C—a precondition for rising productivity that the job to be done by the individual workers should be a very simple one. Sub-division of operations and elimination of variety both brought major benefits to productivity. But for this fact that there was one rather obvious explanation—the lack of serious operative training. At D there was no training school. New operatives were placed directly on the main manufacturing lines, and learnt their job as they went along. In such circumstances the value of simplification in work does not appear to need any justification in terms of, say, the greater suitability of women to light repetitive jobs. Certainly in coil insertion at B, an operation which is neither simple nor light, very high rates of work were achieved by women.

But that does not mean that D's decisions to employ more women, and to pay by the hour rather than by results, were of no significance. First, for social reasons, women—particularly young women—are likely to have a shorter working life than men, a fact which mitigates against putting any major investment into their training. Second, we suspect that they would be likely to respond less well to the direct form of incentive used in C—partly because their financial needs are on average less pressing. If this were so, the kind of organisation used at C with its primary reliance on financial pressures to maintain the flow of work would be unsuitable. The factors affecting the comparative responsiveness of men and women to incentive schemes are—as other studies have pointed out—so complex that it would be foolish to say more. It is, moreover, important to notice that forms or organisation will in some measure reflect the forms of payment, and this in itself can make a comparative assessment of the effects of the different forms of payment virtually impossible. Thus a major advantage of the complete segregation of the manufacture of the motors required in bulk, that followed design specialisation at D, was that a flow of work could more easily be maintained despite the absence of financial pressures. But we suspect a third much more general point to be important. The fact is that female labour is cheaper than male labour, and that both were relatively cheap at D. The label of low wages may have acted in the same way as did the label of high wages at B, in indicating the quality of performance expected—and therefore the quality of performance that will be aimed for. Which leads us to suggest that the wider employment of women and the absence of a direct incentive scheme at D were symptoms rather than primary causes of its low productivity.

But even so the employment at D of a much higher proportion of women has to be taken into account in assessing its performance. In our society women are less well paid but are nevertheless probably gainfully employed less than they would wish, and it has to be counted a sign of efficiency to employ them in preference to men. More tentatively—because of the impossibility of isolating native talent from talent put there by training and experience on the job—it also has to be counted a sign of efficiency to take less than the best labour of similar grades from the market. And this study does suggest—most notably in the comparison between B and C, but also in the comparison of productivity on washing-machine motors at B and at D—that concentrated attention on the rate of work may lead to the employment of better labour than is really necessary for the job. But something more than a single-period comparison would be required to test this; for what matters is the potentiality of growth in the various approaches. The fact that both C and D in their different ways were branching out in new directions suggests that there may be more to be said in the longer run for B's approach than emerged in this period. As regards D in particular, in this period many of its features were a hangover from earlier days. The impact of the recent expansion of its engineering staff had only been felt in the limited sector of washing-machine motor manufacture, and, as we saw earlier, its low productivity had led to a polarisation in output which substantially complicated the manufacturing problems it faced. It was certainly not a principle of its management to compete by combining low productivity with low pay. And in fairness it must be stressed that its employment and pay practices, however much they may have been associated with its low productivity, certainly did not appear to inhibit productivity growth. In the period covered by our inter-temporal studies, D's performance compared favourably with that of the other two factories.

Nevertheless the fact—whatever its particular source—that at this time high productivity did not necessarily confer competitive advantage in direct labour cost is of profound importance. Even though direct labour cost constitutes only a quarter to a third of the total manufacturing cost other than direct material cost, and even though direct labour may be saved by substituting other types of expenditure (e.g. on machinery), comparative direct labour productivity still remains the best guide, if not to efficiency in the use of labour, at any rate to the technical competence with which the actual job of manufacturing has been done. This must not be pressed too far; it is possible to spend too much on achieving a high rate of output from the direct labour force—both by devoting too many other resources to the task and by overlooking other sources of economy, matters which were investigated in Article II for direct materials, and which we shall investigate further in our next article on overheads. But since the purpose of much overhead expenditure is to enable the direct labour force to become more productive, the level of direct labour productivity is therefore a guide to the extent to which overhead expenditure has been successful. So it is decidedly serious to discover how unimportant for direct labour costs differences in direct labour productivity appear to have been in this industry. How much this has to do with the systems of payment in the two more productive factories it would be difficult to say. Undoubtedly these systems were important at B and C in the achievement of the productivity they did achieve, and undoubtedly they provided an automatic link whereby rising productivity went with rising pay. Indeed in B—though not in C—nearly all the direct savings from higher labour productivity would be automatically passed on to the workers. Of course, some connexion between rising pay and rising productivity has to be expected even in a factory such as D, without a direct incentive scheme, if only because rising productivity must enhance the bargaining power of labour. Even so it is not unlikely that the existence of an automatic link—certainly one as generous as B's—will lead to the passing on of rather more of the savings from growing productivity, with the effect that the factory without such a scheme should be able to remain competitive in direct labour cost with a lower rate of growth in productivity than one with such a scheme. Whatever the reasons for the relationship between productivity and pay it does mean that progress towards higher productivity via competitive pressures is likely to be inhibited. This industry is a dynamic fast-growing industry, and, though to some extent fluctuations in output may lessen competitive pressures by providing periods in which demand is high enough to permit capacity-working in all factories, it seems to us possible that in rather less dynamic industries long-period co-existence between the productive and the unproductive is even more likely to be compatible with competition.

We also want to stress another rather different barrier to progress. In describing and analysing the approaches of B and C we have tried to bring out that these approaches were genuinely alternative approaches to nearly the same manufacturing problem. And even D's problem was not all that different in essence; the specialisation of washing-machine motor design was an economy move and not the result of a difference in opinion between D and the others as to the kind of motor wanted by washing-machine manufacturers. True, the existence of other designs at D—with the result that its manufacturing problems were complicated by the wider markets it was attempting to cater for—did mean that the case for specialisation there was particularly strong; for there was less scope than in the other factories for realising those economies of scale implicit in the design of motors. But even if these other designs had been non-existent, the case at D for design specialisation would still have been strong, on the grounds that it permitted a better utilisation of relatively unqualified labour. And thus it could be said that there were three genuine alternative approaches to a similar manufacturing problem. Each had particular merits—and the choice between them depends in part on the composition of output to be made, for it was a consequence of the differences in approach that relative motor costs in different factories were very different. As a result, the forces of what we term *de facto* specialisation came into play, and each factory tended to get the markets that showed its approach to the best advantage. But *de facto* specialisation is something very different from deliberate specialisation. *De facto* specialisation lessens the competitive pressure; but it does not confer the real advantages of deliberate specialisation, which are likely to stem from a refusal to cater at all for the kinds of uses to which one's manufacturing approach is less suitable. For it seems to have been impossible to realise simultaneously all the economies of scale implicit in the great similarity of motors for different uses and those implicit in the bulk demand for a few types—at least on the scale of output prevailing in any of these three factories.

But we do not wish to end in this gloomy fashion; for the fact is that in all these three factories the inter-temporal comparisons did show that productivity was rising fast, and that the barriers were not wholly inhibiting either competitive pressure or progress. The sources of growth were far from uniform, even in the two where the pattern of advance was largely one of doing a more competent job within an essentially unchanged framework. Indeed it does stand out from our survey that at any rate in multi-product factories—but we suspect also in single-product factories—there is not one sort of approach that leads to success. Factories such as B and C, essentially serving a similar range of markets in a similar way, could scarcely be expected to have more differences than those we have observed—in wages and personnel policy, in their attitudes to mechanisation, standardisation and machine utilisation. All these various strands were significant, and none could usefully be assessed in isolation. For a high, or a rising, rate of productivity cannot be achieved without some coherent approach. It is not a question of copying this or that gimmick, whether it be a technical trick or a particular form of labour encouragement. Such things are important; but they have to be developed within a framework. A factory must have a definite conception of the broad lines along which it will advance to achieve greater competence in the job being done. And in many ways the most interesting thing about the whole comparison is the similarity of results achieved by approaches in one of which technical, and in the other of which human, considerations seemed to predominate.

ON THE BENEFITS OF BEING DENIED THE OPPORTUNITY TO 'GO SHOPPING'

By G. D. N. Worswick

Introduction

This paper is concerned with the idea that a fixed price agreement among manufacturers may confer a benefit upon the public, inasmuch as buyers are spared the trouble and expense of shopping around which would (it is suggested) be incurred if there were no fixed price agreement and (by implication) no uniformity of price as between one manufacturer and another.

This argument formed the basis of the judgment by the Restrictive Practices Court in favour of the Price List of the Black Bolt and Nut Association, delivered on July 15th, 1960. As is well-known, under the Restrictive Practices Act, 1956, restrictive agreements between two or more persons carrying on business in the production or supply of goods are contrary to the public interest, unless the parties to the agreement can show that at least one of the seven 'gateway' clauses of Section 21 of the Act applies in their particular circumstances. This alone is not sufficient: it is further required that these circumstances must be weighed up against any detriments to the public or to persons not parties to the agreement and a balance of advantage struck. (This is the 'tailpiece' clause of Section 21.)

The particular clause which appears to have carried the day in black bolts and nuts was Section 21 (b) which requires:

> 'that the removal of the restrictions would deny to the public, as purchasers, consumers or users of any goods other specific and substantial benefits or advantages enjoyed or likely to be enjoyed by them as such, whether by virtue of the restriction itself or of any arrangements or operations resulting therefrom.'

The specific and substantial benefit in this case was that stockholders (a form of merchant) and large industrial users were saved the trouble to 'go shopping'.

It is my purpose to examine the economics of this argument *per se*. To do so presents a certain difficulty. This is the first case in which an argument of this kind has been used by the Restrictive Practices Court: moreover I myself have never previously encountered it in the economic literature. Consequently either I must put up my own Aunt Sally, or else I must draw upon the particular case of bolts and nuts. The latter seems to be the wiser course. In taking it, that is to say, in drawing facts and arguments from this particular industry, and this unique judgment, I run the risk that someone might say: 'Bolts and nuts are *sui generis*: what applies to them cannot be applied elsewhere.' Whether anyone would say this I do not know. What I would like to make clear is that, so far as one can distinguish the economic from other aspects of a problem, I do not believe that bolts and nuts are unique. If, that is to say, we characterise these goods by various attributes (e.g. their cost in relation to the final products in which they are embodied, the type of buyer and user, the number of manufacturers, the degree of standardisation of product, or any other classificatory criteria one can think of) then it is not possible so to delineate them that no other goods would fall into the same class. On the other hand, at the risk of imputing to the Court ideas they did not hold, one can think of factors such as cost, or frequency of purchase, in which bolts and nuts might be thought to differ significantly from other goods, e.g. aircraft carriers, so that what might apply to the one would not necessarily apply to the other.

The Product and its Market

The fastenings[1] are made from mild steel, by two main processes, cold forging and hot forging, in about 3,000 standard shapes and sizes, mostly to B.S.I. specifications. In addition there is a demand for other shapes and sizes which differ from the standard products.

The basic technique of production is, by the standards of modern industry, relatively simple. But, as is so often the case, the very simplicity of the technique allows a high degree of mechanisation, to the extent that the scale of production justifies it. There already exist machines into which mild steel wire is continuously fed at one end and completed bolts are extruded at the other end, without need for direct human intervention.

The Black Bolt and Nut Association has 44 members and between them they produce about 90 per cent of the fastenings. Imports are at present negligible but exports of £1 million in 1959 constituted about 8 per cent of the home trade sales of £12½ million. The largest single producer was responsible for over one-quarter of the home trade and the three next largest for a further 30 per cent: at the other end of the scale one half of the producers produced only 7½ per cent of the output.

The fastenings are intermediate goods—destined to be incorporated in other manufactured goods, e.g. railway wagons, buildings, bridges and a multitude of other products. The cost element of fastenings in such final products is, as a rule, trivial: the highest proportion of fastening cost to total was 5 per cent for some work of constructional engineers. Though fastenings can be purchased at retail from ironmongers—the bulk of sales is either direct from producer to the industrial user or else to stockholders, who in turn supply mainly industrial users, though they do also sell to ironmongers and the like for the retail trade. The nature of the agreement, so far as it affects prices, is that there is a uniform price for each product specified in the Price List, and the actual price to be charged to every buyer (except for a certain list of ' large users ' for whom a separate system of price determination was adopted) will be this price with certain plussages or discounts, also laid down, in accordance with the conditions of sale. It will be convenient to ignore these plussages and discounts and imagine simply that there is a uniform price charged whenever a manufacturer sells his fastenings to a buyer. We shall, however, keep in the picture two particular discounts, one of 7½ per cent which is to be given to any member of the Association if he buys from another, and a uniform discount for stockholders (5 per cent or 7½ per cent according to the size of their stocks and amount purchased from members). The significance of the first of these discounts is as follows: no manufacturer, not even the largest, makes all varieties and sizes of the fastenings, and since 1945 it has been the practice for members to acquire from other members such types or sizes of the fastenings ordered from them by their own customers as they cannot conveniently or economically manufacture themselves. This inter-trading tends to be between the larger producers, who concentrate upon long runs of the more important standard sizes and the smaller manufacturers who make the sizes in smaller demand and ' Off-Standard ' and ' Out-and-Out Specials '.[1] Inter-trading undoubtedly permits greater specialisation among manufacturers—which is economically commendable since the economies of large-scale production of any single size of fastening are obvious, too obvious to call for any detailed substantiation. It should, however, be emphasised that such inter-trading is not the *only* way of securing specialisation in production among manufacturers while giving the maximum choice of variety to the users. It is interesting that while there are ' stockholders ' in this trade, who are a kind of wholesaler, they do not perform the wholesaling function on such a scale as is found in some other trades. The inter-trading agreement bypasses, or substitutes for, the wholesaler.

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[1] Black bolts and nuts with a coarse finish are distinct from bright bolts and nuts, which are covered by another association and agreement. Besides black bolts and nuts two other classes of fastening, carriage bolts and nuts and railway fastenings, come under the present agreement. We follow the practice of the Judgment and refer hereafter to ' the fastenings '.

CONTENTMENT AND THE ILLEGITIMATE BABY

This section is a digression, taking up some points which occur in the Judgment which may conceivably have influenced the Court in the matter of the benefits of not shopping, although it is not easy to deduce to what extent, if at all, they did in fact.

The first concerns the reasonableness, or otherwise, of the *prices* actually fixed. ' If the proof of the pudding were in the recipe, one would expect consumers to find it an unpalatable comestible. It is significant, however, that not only has there been no evidence of consumers being dissatisfied with the prices charged either generally or in relation to any particular item, but the Registrar's witnesses have not contended that the prices have been unreasonable, and all consumers and stockholders called have expressed their satisfaction with the prices and the price-fixing scheme.' (Judgment p. 15, B.C.D.).

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[1] The distinction is that ' Off-Standard ' specials are near enough to standard specification for uniform plussages or discounts to be appended to the Price List. The prices of ' Out-and-Out ' specials are freely negotiated between producer and buyer.

With all respect I do not think that the absence of specific complaints establishes the reasonableness of prices: nor, for that matter, would I attach a great deal of weight to a specific grumble from a customer. We normally talk of being 'overcharged' in situations where alternative prices are in fact possible, and even customary. 'That tailor overcharged me for making that suit.' 'Those window-cleaners overcharged.' The ordinary man's usage of the notion of being overcharged simply does not apply where there is, and has been for some time, only one price at any moment for all the alternative fastenings. To substantiate a claim of overcharging the complainant would have to go into the question of production costs and profits of the manufacturer. His willingness to do so depends among other things on: (1) the size of the bill for those goods in relation to other costs of production of his own product, (2) whether he believes that he is being charged more for a particular product than his own competitors are being charged for theirs.

With regard to (1) there is not very much to say. Two conflicting proverbs deal with it: 'Penny wise, pound foolish' and 'Take care of the pennies and the pounds will take care of themselves.' One can go a little further and argue that the business of seeking economies is not worth while if the hoped-for economy is less than the certain expenditure involved in achieving it. Sending a letter, with a 3d. stamp, to reclaim a debt of 3d. is barely worth while. The incentive to make economies, be they large or small, also depends on who is paying. The railway passenger travelling on expense account is indifferent to the railway fare. Many of the users of fastenings are producing goods to order, the price of the goods being made up of costs involved plus a 'reasonable' profit. If the price of fastenings goes up, it simply calls for an adjustment of their own quotation and is 'passed on'. It is noteworthy that the most common complaints against fixed prices come from public authorities. They are liable to criticism for wasting public money, and therefore are more constantly on the alert to ensure that the prices they pay are no higher than they need to be.

A firm is more likely to worry about the price of a raw material or component if it believes that it is being obliged to pay more for it than some of its competitors. If there is a uniform price, which all must pay, what does it matter if that price is, in some sense, too high? If a protest were successful the benefit would be shared between the firm making it and its competitors.

I would venture a tentative qualification of this. Firms are more likely to complain about fixed prices if they themselves produce for and sell in a highly competitive market. This is especially so if they are in the export trade, for then they may think that they are being charged a 'high' price for materials, while their foreign competitors are not. Such complaints may be based on fact, or not uncommonly reflect distrust of fixed prices as such.

The second point concerns the reasonableness of *profits*. 'It is common ground that the profits made by the industry, whether based on turnover or on the return on capital employed, have certainly not been excessive.' (Judgment p. 15 D). Comparisons were made between the *average* rates (from a rather small and haphazard sample of firms) of return in bolts and nuts with various *average* rates in other industries and with one firm in a quasi-monopoly situation. An agreed definition of 'reasonableness' derived from first principles is unattainable. A dyed-in-the-wool Marxist, after all, would simply say that reasonable meant zero. And, while among those who accept that profits have an economic function (e.g. to elicit 'entrepreneurship' or 'risk-taking') there might be found some acceptable form of words, there is still the question of 'cashing' the formula in terms of actual figures: 17 per cent is reasonable here, 10 per cent there, and so forth. The best one can do, and it is precious little, is no doubt by comparison with similar cases.

Anyone who has studied profit figures is well aware that in nearly all market conditions from the most competitive to the most monopolistic (e.g. well-policed fixed price agreements) there is encountered a range of profit rates (whether on capital or turnover) for the different firms. Now if the *average* is declared reasonable does this entail that firms with above average are 'unreasonable'? A particular firm has higher than average profits because, say, it is more efficient. Is that unreasonable? And firms with less than the average: are they unreasonably low? In principle some progress might be made by studying the spread of rates. If one could set up a 'reasonable' *dispersion* of profits about the average, one would have a standard for judging a particular case. Or if one could ascertain whether the dispersion were widening, or narrowing, through time this might provide some sort of pointer. But even with a full-scale study of this kind there would still be plenty of room for disagreement as to whether the results were reasonable or not. One thing, however, is quite clear. An unqualified comparison of averages is valueless.

Thirdly, the Judgment stressed that the contribution of the cost of fastenings to the final products in which they were used is in most cases trivial. The implication appears to be that even a sizeable change, say 10 per cent, in the price of fastenings is too small in its effects to be worth fussing about. This is the doctrine of the illegitimate baby. So long as we confine our attention to a particular firm or trade this argument seems convincing. But if *every* firm, in every trade, put its price up 10 per cent the result would not be negligible. The procedure of the Restrictive Practices Act inadvertently encourages the use of the 'illegitimate baby' argument. Some of the arguments against restriction in a particular case are simply the application to that case of principles of a general nature, whose importance are more easily appreciated in the wider than in the narrower context. While an economist may be able to bring evidence, which is more than mere opinion, that a certain type of restriction tends to have such and such deleterious consequences over a fairly long period of time, he may be quite unable to bring conclusive evidence that the specific restriction in the specific instance has done a measurable amount of harm in a specified period of time. If 'evidence' is to be confined only to the latter, then in many cases there is virtually nothing an economist can contribute to the proceedings.

The Benefits of not Going Shopping

The not going shopping argument is put very briefly in the Judgment, as follows:

> ‘ The advantage of the uniform price to the stockholder is, put colloquially, that he does not have to ‘ go shopping ’. He knows the price he must pay from whatever manufacturer he buys: date of delivery is the only matter for negotiation. If prices for individual items of the many hundreds of sizes and shapes which he has to stock varied from manufacturer to manufacturer, he would be compelled to make many more enquiries before making his purchases and his administrative costs would be increased. The margin of 7½ per cent upon which he at present operates and which covers not only his overheads and administrative expenses but a return on his capital locked up in stock, would, we are satisfied on the evidence, be scarcely adequate to cover the additional cost in ‘ going shopping ’, while the profit margin available on the present fixed price leaves little room for any appreciable reduction in prices under free competition, although it may be that there are some imbalances in the present basic price list which under free competition might be adjusted by the price of some items rising and others falling. In the net result, however, we see no prospect of the stockholder recouping his additional expenses of ‘ going shopping ’ save by raising his own prices to the purchasers.’

This is the argument upon which the Judgment in favour of the Price List rests and it merits careful examination.

(1) Let us look first at what is implicit in the first three sentences. It is clearly implied that removal of the restriction *would* lead to manufacturers quoting varied prices for each, or many, of the numerous standard shapes and sizes. To secure uniformity of price, it appears to be argued, a price agreement is *necessary*. This is not true. Uniformity of prices can occur in a wide variety of circumstances.

Consider, for example, the price of gas. We suppose that consumers' preferences for various types of fuel are similar so that the demand schedule for gas will be much the same in towns of equal size and wealth. Suppose that each town's gas was supplied by a single producer, and suppose there is no statutory control over prices. If each producer is free to charge what the market will bear, and chooses to maximise his profits, then the price of gas will be much the same in all towns of equal size and wealth. That is to say, a number of monopolistic markets, completely independent of one another, could yield uniformity of price.

A completely different kind of case will also yield uniformity, namely, when a number of producers supply a homogeneous product to the same market. For in this case if one producer raises his price while the others do not, he will very soon lose his customers to his competitors.

If we turn things the other way round and are told that there *is* uniformity of price for a particular product we cannot deduce from this fact whether there is a price agreement or not, and in the latter case the relative proportions of competition and monopoly present in the free market.[1] The mistake of the Judgment is to contrast an actual situation with a purely hypothetical one of the Court's own invention, and then to adjudge the former the better one. What they have failed altogether to consider is whether their hypothetical case is one which is *likely* to occur if the restriction were removed.

(2) What would in fact be most likely to occur if the restriction were removed? No one can be certain. My own guess is that the most probable outcome would be *price-leadership* by the largest producer. It is pretty nigh certain that at least that firm would issue a price-list of its own, for the products it manufacturers. Other firms would, when quoting prices, either reproduce this list, or one of their own, or else refer their customers to it. When, for example, a rise in costs occurred, e.g. in the price of steel, the other producers would simply take their cue from the leader. Once the restriction were removed, however, price competition would become possible. A firm with a cost advantage *might* decide to have a go. It seems to me rather unlikely that it would cut the prices of some products and not others (this could happen if the cost advantage were due to the invention of a machine making only a certain size range): more likely it would simply quote 'Leading Firm's Price List less x per cent discount.'

At the moment when one firm, or group of firms, initiated a change in prices there would be at least two prices for a given size of fastening being quoted in the market. Would this difference persist? There are some reasons why it might. If, for example, a particular set of buyers have become accustomed to buy from a particular stockholder or manufacturer, they might not bother about paying the same old price, *even if they know* that others are producing some or all of their needs a little cheaper. They may do this out of sheer habit, or because they think their present supplier will give them speedier delivery now and in the future, whereas if they switch their custom they may take a lower place in the queue in times of shortage. Or they may believe that the quality of fastenings presently supplied to them is that much better than the now cheaper ones available elsewhere.

On the other hand if buyers believe that such quality differences are negligible (and I am inclined to think that this must be their view in many cases, since, with inter-trading, they can never know for certain which manufacturer is going to make which fastening), some will begin to switch custom to the cheaper lines. And this will put pressure on those who have not cut prices to reduce them into line with those who have. This is the very *process of competition* which the agreement inhibits and which, in my view, in this particular case would be likely to bring about a restoration of uniformity of price following a departure from a previous uniformity initiated by one, or more, firms.

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[1] For a more exact treatment of this question cf. Chamberlin, *Theory of Monopolistic Competition*, seventh edition, pp. 88–9.

Curiously enough the Judgment recognises this pressure of uniformity in explaining why stockholders sell at List Prices—even though the Stockholders' Agreement does not require them to do so.[1]

So far, then, it would seem that the Judgment's argument is based on a false major premiss—namely, that the end of the restriction would mean the end of uniformity. But this is not all.

(3) Following up their own hypothesis of varied prices, the Judgment argues that ' the stockholder would be compelled to make many more enquiries before making his purchases and his administrative costs would be increased '. It seems that the Court is not thinking here of the stockholder as a merchant selling out of his own stock. If he were, why does he not quote his own price? The Court must be thinking of the stockholder primarily as an intermediary buying agent. They visualise him telephoning all 44 manufacturers to find out their ' today's prices '. But, if the stockholder is merely an intermediary, he must already have to do a bit of telephoning to find out about availability—a matter of some importance to buyers, according to the Judgment. Why are enquiries about price so much more expensive than enquiries about availability?[2] Secondly, what *compels* the stockholder to do all this telephoning? Is it because his own customer will be cross if he does not deliver the fastenings for the lowest possible cost? If this is the reason, it postulates a degree of keenness to economise on the part of the buyers which the Judgment goes out of its way to explain they do not have. No one is *compelling* the buyers to go shopping: if they are lazy about price, why cannot the stockholder be also?[3] But if the buyers *are* keen to economise then we cannot continue to assume that differences in prices will continue to rule—the pressure of competition will eliminate them—in which case the extra telephone calls need not be made after all.

(4) The Judgment asserts that present margins are, ' on the evidence ', insufficient to cover the cost of these (hypothetical) extra enquiries. No hard evidence was in fact brought in about these extra costs.

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[1] Stockholders, it argues, will not sell below List Prices because they would ' be naturally hesitant to endanger their relationship with their suppliers by undercutting them '. They will not sell *above* List Price, since Price List No. 3 is available to their customers, ' so that only rarely would they be likely to find a market at prices higher than those fixed by the Association's Price List.'

[2] I have here followed the argument on the Court's own ground. If, as I think they would, manufacturers issued Price Lists, or catalogues, or referred to the List of one or more price-leaders, these inquiries about price would not be necessary at all.

[3] There is an argument which has been used with regard to the purchase of consumer goods—which we can call the argument of ' housewives ' neurosis'. It takes two forms. In the first Mrs. Jones knows that the same toothpaste is being sold at different prices in different shops. She goes round and round finding lower and lower prices, but can never bring herself to buy, just in case she sees a still lower price in a shop on the way home. In the second case, Mrs. Jones does buy, but when she sits down for tea with Mrs. Robinson, suffers agonies when she learns that the latter did find a lower price. I have been told that people accustomed to a fixed price world do suffer these neuroses if suddenly transported into a variable price world, e.g. United States (in some goods) or an oriental bazaar, but that for those of strong constitution the effects quickly wear off.

The Court did not invoke this aspect of not shopping. Nor would it seem appropriate to invoke it for merchants and manufacturers who make a living from buying and selling.

(5) Suppose margins were insufficient? Then, says the Judgment, the stockholder would recoup his additional expenses by *raising his own price to the purchasers*. But this presupposes once more a monopoly position. *If* buyers are keen, and *if* stockholders raise prices, buyers will switch to direct purchase from the manufacturers. If buyers are *not* keen, then stockholders are under no compulsion to act as though buyers were keen and waste money on telephone calls to save the buyer some money to which he is—*ex hypothesi*—indifferent. Once again, the *inability* of stockholders to move out of line from manufacturers is a point which the Judgment itself has made in a different context.

(6) Would not inter-trading be impossible without the agreement? Why should it? If there is keen competitive pressure prices will be uniform, so that there is no change. If buying is not keen then different prices will rule for a particular fastening. A buyer orders a consignment of fastenings from manufacturer M. M. replies: ' I can give you items 1–10 myself, at such and such a price. Items 11–15 I will get for you and send you the bill. I do not at the moment know what it is.' But *ex hypothesi* the buyer does not care what it is. He just pays up. It is true that if, for example, a uniform 7½ per cent discount were kept in being, M. could do a trifle better for himself by looking for dearer, rather than cheaper, fastenings to be supplied by his colleagues. But the buyer is presumed not to mind. If he starts minding and starts shopping around, the higher prices will tend to come down. That is how competition works.

CONCLUSION

To sum up: the not shopping argument of the Judgment is based on a false premiss and in addition contains a number of contradictions. How many contradictions is hard to say, since some parts of the arguments are contradicted by statements in other parts of the Judgment. It is not possible to particularise and point out what appear to be the more important mistakes. It will suffice to say that I believe that no case has been made out that price fixing of fastenings confers any benefit of the kind proposed in the Judgment.

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OBSOLESCENCE AND TECHNICAL CHANGE

by C. P. KINDLEBERGER[1]

In the 1930s *The New Yorker* ran a series of cartoons by Gluyas Williams in which a 'Sceptics Society' tested aphorisms, such as whether or not it was really possible to make a silk purse out of a sow's ear, or whether love laughed at locksmiths. Occasionally, the Society tackled simultaneously two rules of conduct which claimed generality but which were antithetical. Is it wise to look before you leap, or is he who hesitates lost? The same conflict can be found in economic growth between the advantages and handicaps of the early start. To many, like Myrdal, growth is a positive feedback process: nothing succeeds like success, to him that hath shall be given, the rich get richer and the poor get children. At the same time there are many in Britain and other developed countries who believe in the penalty suffered by the pioneer,[2] and the benefit of the latecomer with his opportunity to construct his equipment along the most up-to-date lines. It is frequently suggested that it is a positive economic gain to lose a war, or at least to have a great deal of capital equipment destroyed in it.

The disadvantages of the early start have been examined immediately after the war by Jewkes[3] and Jervis,[4], in the middle fifties by Frankel,[5] and recently in a book by Salter.[6] Jewkes and Jervis are disposed to dismiss any alleged handicap imposed on economic growth by the existence of ancient capital equipment. Existing capital, in whatever condition, is a free gift from the past. Its owners always have the option of destroying it and starting again, just like a developing country or a country recovering from war. Frankel argues that 'interrelatedness' of capital equipment in various industries and plans means that technical progress has been inhibited by large quantities of existing equipment. It was impossible to adopt a more economical freight car size on British railroads without modifying British tunnels, bridges, railway stations, and so on which had been built to the original smaller scale; or to adopt ring spindles in cotton textiles, without readapting weaving techniques to the altered yarn. But he conceded to his critic,

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[1] This paper was written during the tenure of a Ford Faculty Research Fellowship. The writer benefited greatly from the discussion of a seminar at the University of Birmingham, at which some preliminary findings were presented.

[2] Thorstein Veblen, *Imperial Germany and the Industrial Revolution*, New York, Macmillan, 1915, p. 128 'The British have not sinned against the canons of technology. It is only that they are paying the penalty for having been thrown into the lead and so having shown the way.'

[3] John Jewkes, 'Is British Industry Inefficient?' *Manchester School*, Vol. XIV, No. 1 (1946), pp. 1–16.

[4] F. R. J. Jervis, 'The Handicap of Britain's Early Start,' *Manchester School*, Vol. XV, No. 1 (1947), pp. 112–22.

[5] Marvin Frankel, 'Obsolesence and Technical Change in a Maturing Economy', *American Economic Review*, Vol. XLV, No. 3 (June 1955), pp. 296–319.

[6] W. E. G. Salter, *Productivity and Technical Change*, Cambridge, Cambridge University Press, 1960.

Gordon,[1] that old equipment was at least equal to none, and possibly better: one always retained the possibility of starting over again.[2] Slater has examined in theory and empirically how technical change takes place and what explains the width of technical practice existing side by side in a given industry.

The present paper then covers familiar ground. Its viewpoint, however, is opposed to that of Jervis, Jewkes, Gordon, and Salter, and supports Frankel before his concession. It holds that there may be a penalty in the early start, if institutions adapt themselves to a given technology, and if static patterns of capital replacement develop as habits. The method of exposition is analytical, but uses illustrative material from British railroading—the example made by Veblen in 1915—and from various secondary sources on industry.

The causation runs from technical change to growth, rather than from growth to technical change. Technical change is assumed to be a major force producing growth, along lines made familiar by Abramowitz and Solow, in contrast to the Harrod-Domar growth model which can operate with a fixed technology. And while the effects of technical change will be felt more with more gross capital formation, it is neither necessary nor useful to insist that the rate of technical change is constant in time or a function of gross capital formation. Gross investment is not a sufficient condition for technological change. As W. A. Lewis has pointed out, steel capacity doubled between 1896 and 1913 without leading to significant improvements in technical practice.[3] And Humphrey Cole who has studied locomotive replacement on the Great Western Railway observes that technical progress does not proceed in an even flow, but in fits and starts.[4]

Economic Factors

Frankel poses the problem in terms of a choice between an existing and a new technology when a substantial amount of capacity is needed to replace capital which suddenly wears out, like the one-horse shay. The choice is made on the basis of a formula, involving, for each process, the rate of interest, the ratio of fixed to variable cost, the amount of fixed cost, the durability of capital, the elasticity of demand, and the number of components which have to be altered. The impact of most of these variables is obvious. Interrelatedness is the effect of the number of components. The more components that are affected by the new method as contrasted with the old, the less attractive will it be to entrepreneurs. Frankel concedes that an old technology may be preferred to a new for institutional reasons—largely archaic patterns of thought, or because of diminishing returns due to a fixed factor, which limits expansion,—though his model involves expansion only when the minimum scale of the new technology exceeds the capaity of the capital worn out. But his main explanation for the slowness of British technological change, and the existence of much obsolete and obsolescent capital equipment in 1913 or 1929, or as late as 1939, is interrelatedness, the possibility that in a complex economy a change in one element of production, transport, raw material supply, and within production, various components, will entail other capital changes because of the complex physical interrelations which exist in a modern economy.

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[1] Donald F. Gordon, ' Obsolescen and Technical Change: Comment ', *American Economic Review*, Vol. XLVI, No. 4 (September 1956), pp. 646–52.

[2] Marvin Frankel, ' Reply ', *ibid.*, pp. 652–56.

[3] W. Arthur Lewis, ' International Competition in Manufactures ', *American Economic Review, Papers and Proceedings*, Vol. XLVII, No. 2 (May 1957), p. 583. The same phenomenon occurred after 1870 in cotton textiles and in coal, with capacity expanding but the rate of increase in productivity slowing down markedly. See also W. E. Minchenton, *The British Tinplate Industry*, Oxford, Clarendon Press, 1957, p. 35, who says that the industry had no major change in technique for 200 years.

[4] See his ' Great Western Locomotive Replacement ', to be published in a later issue of THE BULLETIN. Between 1891 and 1906 a new type of locomotive was produced every three years by the Great Western Railway, following a long period when technology was static, and followed by no new prototype until 1945. I am grateful to Mr. Cole and Mr. David Holland of the Oxford Institute of Statistics for making available their useful studies on locomotive and bus replacement, and for discussion. The *locus classicus* for the view that technological progress moves in fits and starts, as Paul Streeten reminds me, is Schumpeter, *Business Cycles*, Vol. 1, p. 102.

Salter's model does not lean on a choice between techniques to replace a portion of capacity which is suddenly lost. He distinguishes between the scrapping of old capacity and investment in new, which have no necessary relationship to each other. An old technique, which wears out only over time, will be scrapped when it is unable to cover its variable costs. New investment involving a new technique will be undertaken only if it is able to earn supernormal profits. In equilibrium, the price of an output will equal average variable costs on the old method, which in turn are equal to average full costs, including normal profits, on the new method. Salter is not concerned with interrelatedness. To him the critical variables determining when it is useful to undertake new investment with new technique are factor prices: the existence of out-moded capital equipment is an indication not of ' inefficiency ' but of relatively cheap labour which keeps variable costs low on the old technique, which is assumed to be labour-intensive, and high interest rates which keeps fixed costs high on the new technique.

Several other economic factors are relevant. One is competition. Under less than perfect competition, old techniques can be kept covering more than variable costs by high prices, so long as entry is limited and the superprofits available to the new technique do not expand production.

Another is the second-hand value of equipment. The variable costs which the old technique must cover, in Salter's model, includes a normal return on the site value, working capital and the second value of the equipment.[1] Salter is not disposed to pay much attention to the influence of the second-hand market but in some markets, such as that for automobiles today, and for ships before World War I,[2] a brisk second-hand market assists technological change by raising the variable costs on the old method, which must earn a return on this second-hand value, or reducing the capital cost of the new method, if its capital requirement is calculated on a net basis, *i.e.* cost of new equipment less value received in sale of old.

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[1] Salter, *op. cit.*, p. 54.

[2] The British merchant marine maintained superior operational efficiency prior to World War I, in contrast with the industries mentioned in footnote 3, p. 282. One element in this was the competition for mail contracts with their emphasis on speed. But the second-hand market in ships doubtless contributed. At the peak of second-hand sales, in 1911, Britain built 1,000,000 tons of new shipping, of which 300,000 tons was sold abroad. Another 485,000 tons was sold abroad second-hand. See the *Statistical Abstract for the United Kingdom*, 1913. The net expansion in tonnage at 215,000 tons was much smaller than the 485,000 tons modernized.

Third is the quasi-economic factor that decision-makers are always a scarce input, that decision-making has a high cost, and that the total return to the firm may be optimized in this circumstance, if decisions are taken by rule of thumb or habit rather than as a consequence of cost calculation. In a world where decision-making is a free factor, this is irrational, and approaches Frankel's institutional impediments to technical change. On a more realistic view, however, it appears that the models of Frankel and Salter both call for more or cheaper, rationality, than is likely to be provided. Where management cannot or will not make decisions on the basis of cost analyses, rules of thumb have their use;[1] what is important is to see that these rules facilitate rather than inhibit technical change.

Interrelatedness

It is not clear from Frankel's discussion whether his interrelatedness is merely 'lumpiness' or 'indivisibility', or something more; and if the former, whether technical change is stopped because of the large size of the investment which does not pay when a smaller one involving fewer components would have; or because the firm cannot borrow to undertake the larger investment, despite its remunerative quality, because of imperfections of the capital market which limit the borrowing of a single firm. Each interpretation is possible.

Let us take the size of British freight cars, on which Frankel quotes Veblen, writing in 1915, and could have cited the 1885 authority of Hadley.[2] It has been agreed for a long time that these cars are inefficient. To enlarge them from 10 to 20 tons capacity would have raised earning capacity 100 per cent, but tare weight only 33 to 50 per cent, and capital costs 50 per cent. Current maintenance would be reduced 25 per cent per ton-mile, shunting would fall, and locomotives could haul pay loads up to 25 per cent greater.[3] The most efficient size for coal wagons has been estimated at 24½ tons capacity (plus 10½ tons tare), which would stay within the critical limitations of size (9 feet width, 12 feet 10 inches height) and of two axles limited to 17½ tons per axle.[4]

Two basic reasons have been given for the failure of British railroads under private ownership to move to a more efficient size of freight car. We restrict the discussion to coal cars, since there is a further complication with miscellaneous merchandise that the average load per car has been well below capacity, haul has been short, and in the absence of an organization like the American Railway Express Agency speed has been furnished for numerous small retail shipments by the railways themselves.[1] In coal, the retention of the 10-ton car is sometimes said to be due to the impossibility of changing it without also modifying 'terminal facilities, tracks shunting facilities'[2] which made the cost of change prohibitive. Again, however, the major impediment is said to have been the fact that the coal wagons were owned by the coal mines and not by the railroads.[3]

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[1] See Cole, *op. cit.*, 'The routine element in replacement has definitely been underestimated in most studies and theories of replacement.'

[2] Mentioned by C. I. Savage, *An Economic History of Transport*, London, Hutchinson, 1959, pp. 76–7.

[3] K. G. Fenelon, *Railway Economics*, London, Methuen, 1932, p. 172.

[4] S. E. Parkhouse, 'Railway Freight Rolling Stock', *The Journal of the Institute of Transport*, Vol. 24, No. 6 (September 1951), p. 214.

The technical aspects of interrelatedness do not seem to have held up the movement to more efficient size of cars either through making such a change uneconomic because of the enormity of the investment required, or making it too much for any one firm to borrow. The sums were not large, as footnote 2 above indicates, and railway finance was rarely a limiting factor in the period up to 1914.[4] Private ownership of the coal cars by the collieries, on the other hand, poses a type of interrelatedness which is institutional rather than technical.

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[1] C. E. R. Sherrington, *The Economics of Rail Transport in Great Britain*, Volume I, History and Development, London, Arnold, 1928, pp. 220–21 gives the average load as 5.5 tons, compared to an average capacity of 10.5. The German figures are 7.6 and 15.9 tons respectively, the United States, 27 and 45 short tons. The average haul in Britain was 54 miles, compared with 93 in Germany and 169 in the United States.

Fenelon (*op. cit.*, p. 171) gives the average load at 3 tons, and states that it is so low because of the bulk of shipments. If this is the reason—and the similarity of the ratios between load and capacity in Germany and the United States would seem to bear it out—larger wagons would be more efficient for less than carload lots of merchandise, too. But much of the literature states that the small railway wagon is well suited to the short, fast haul of small shipments, resulting in a low average load per car. See for example, S. C. Williams, *The Economics of Railway Transport*, London, Macmillan, 1909, p. 134; Sherrington, *loc. cit.*, p. 214.

[2] Veblen, *op. cit.*, pp. 126–27. It is wrong to mention track, as there is no necessity to strengthen road bed or bridges, or to modify tunnels, so long as car size is kept within the limits specified in the text, and within 17½ tons per axle. With bogies or trolleys much heavier cars are possible with increased cost. Fenelon mentions in 1932 a 70-ton transformer wagon and a London and North-eastern Railway well-trolley wagon built to carry 110 tons tons or in special circumstances 150 tons (*op. cit.* p. 56).

The primary problem for coal would be to re-equip collieries and ports to take the larger wagons and in particular to modify coal-screens, weigh-bridges and sidings (where curves have to be modified for the increased length of the wagons) in collieries, and hoists and tips at the ports, along with the work-sidings of certain large-scale coal consumers. (Fenelon, *ibid.*, 172). Fenelon estimated the cost of all alterations, however, at about £8,750,000 (in 1932) and the net saving at £2 million per annum.

[3] Of the 1,320,000 freight cars in Britain in 1930, 630,000 were privately owned, and 90 per cent of these were used for coal. The advantage of direct ownership of cars by a colliery was that it could be assured of a supply of cars. The overall economic loss to the country, apart from any inhibition on technical change, was the necessity to haul empty cars back to their owner, rather than to pool them, with an increase in shunting and in empty running. A. J. Pearson points out in 'Developments and Prospects in British Transport, with Special Reference to Railways', *The Journal of the Institute of Transport*, Volume 25, No. 4 (May 1953), p. 123, that the acquisition of the coal wagons from private owners by the National Coal Board has enabled the proportion of productive to total miles to be raised from 66.8 per cent in 1938 to 71.3 per cent in 1952.

[4] The problem of inefficient freight-car size may have been affected by an old Railway Clearing House specification for private wagons forbidding carrying capacities above 10 tons, which was modified 'belatedly' in 1902 (S. C. Williams, *op. cit.*, p. 136). But it is not likely that such prohibitions which did not bind the railways themselves were very powerful. The adoption of the Gauge Act by Parliament in 1846 induced the Great Western Railway to abandon its 7-foot gauge only in 1892. Three major conversions had taken place in 1869, 1872 and 1874, but a new merger in 1876 raised the broad gauge track from

A decision to change the size of rolling stock involves investment by the railroad on the one hand, and by the collieries on the other. Even if the rolling stock had been owned by the railroads, there might have been reluctance on the part of the collieries to alter their screens, weigh-bridges and sidings to suit. They could insist that they were under no obligation to undertake investment to benefit the railroads. And the railroads in turn would have difficulty in effecting an adequate distribution of the gains from the new investment, especially given the existence of uncertainty as to what these benefits would be.

For the railroads to guarantee new low rates on larger wagons would have been to have taken all the risk of their investment, and that of the collieries, upon themselves. To indicate only that they would consider new and lower rates if these were justified by operating economies, would have been to assign the risk to the collieries. An attempt to apportion the risk between the two would be equitable but not likely to arouse much enthusiasm. The Great Western and Great Eastern railways adopted 20-ton wagons for their own use for locomotive coal as early as 1897,[1] and the Northwestern used 20-ton bottom-discharge mineral wagons for iron ore, and 40-ton bogie coal wagons from the beginning of the century.[2] In this area, the railroad, not the coal companies, owned the rolling stock. But the Great Western Railway failed to persuade the colliery owners to change, when it offered a rebate of 5 per cent on freight cars for coal in fully loaded 20-ton wagons, and in 1925 reduced charges on tipping and weighing these wagons.[3] Only 1,000 of them came into use.[4] Colliery owners gave the excuse that the bigger wagons resulted in increased coal breakage. But neither ancient example, rebate, nor exhortation by Royal Commission[5] proved of avail until the nationalization of the collieries.

8 to 293 miles. This was worked down to 183 in 1889, and finally converted in 1892 (see H. Cole, *op. cit.*).

This slow move to modernisation and standardization provides an instance of technical interrelatedness. The necessity for new or reluctance to scrap old rolling stock, was the main cost of conversion, apart from labour to shift the rails, since new track was needed only at bends, points and crossings, and very little roadbed. Locomotives had long been built on a convertible basis, with wheels outside the frame for broad gauge work capable of being brought in for standard. Part of the slowness was due not to the investment problem, or the reluctance to scrap rolling stock and traction which could not be converted, but to the management's firm belief that the broad gauge was superior. In Australia, the standardization of gauge is held back partly by the lumpiness of the investment problem involved, but partly, despite frequent Royal Commissions, the difficulty of agreeing among the states.

Note that in the United States 15,000 miles of track was converted from broad to narrow gauge in 2 two days in 1886 (Williams, *op: cit.*, p. 99).

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[1] Sherrington, *op. cit.*, p. 214.

[2] Fenelon, *op. cit.*, p. 171. The London, Midland and Scottish Railway also used 40-ton bogie wagons to carry coal to its own power station.

[3] *Ibid.*

[4] Sherrington, *loc. cit.*, p. 218.

[5] The Reid Report (Report of the Royal Commission on the Coal Industry, Cmd. 2600, 1926) recommended the establishment of a Standing Committee on Mineral Transport. This in its report characterized the system of private ownership as defective, and recommended that the railroads ultimately take over the wagons. In the meantime, it recommended pooling. The Report of the Royal Commission on Transport (Cmd. 3751, 1931) scolded the railways, except the Great Western, for not having moved to larger wagons.

Sherrington attacks the Act of 1921 consolidating the 130 pre-war lines into four major companies for its failure to eliminate private traders wagons, *inter alia* (*op. cit.*, p. 262).

Institutional interrelatedness inhibiting technical change can be compared to pecuniary economies external to the firm. Investment is required of two or more firms. Uncertainty attaches to the yield. A commitment as to the division of the benefits is likely to assign a major portion of the risk, or a substantial risk, to one of the participants which on this account refuses its participation. An investment is not undertaken because of the possibility that the benefit will accrue to others. Where the railroad owns the cars and serves its own purposes—locomotive coal, or fuel for power stations, the more efficient technology is used. Like Rosenstein-Rodan's classic example of external economies in production in underdeveloped countries, vertical integration converts the external to an internal economy which adds to company profits.

Uncertainty may not be the critical block. It may be simple market failure—the refusal of the beneficiaries to offer a sufficient inducement to the firms for which the economies were originally external to undertake their share of the investment. Such market failure may rest in inertia, non-maximizing behaviour, etc. But it is likely that uncertainties about the division of costs and yields will contribute to it.

The same analysis applies to the equipment of freight cars with automatic brakes. Such brakes were fitted to passenger cars after 1878 in response to public and governmental demands for safety on the one hand,[1] and the need for higher speeds on the other.[2] The higher speeds were partly a response to the pressure of competition for passengers. But they were also economical, permitting more traffic to move over a given right of way. Required were bigger and more powerful locomotives, which were developed, and brakes which were forthcoming for passenger trains, for a few special commodities, like flowers and fish, but not for general or coal goods traffic. The Great Western Railway fitted some freight cars with automatic brakes, such a nuisance was the short, slow freight train. But by and large little was done to fit automatic brakes to freight wagons, and the question of whether to do so and to what extent, is still under debate.[3]

The arguments for and against continuous brakes are set forth in the article by S. E. Parkhouse in the *Journal of the Institure of Transport* already referred to. The disadvantages include the capital cost of the brakes on cars (£31 millions), for fitting locomotives not equipped for brakes (£400,000), the increased costs of shunting (£800,000 to £1 million a year), of testing brakes monthly (£750,000), of a heavy overhaul every two and a half years, with the need for more wagons to replace those taken out of service for testing (£2,500,000), and for more coal to pull the weight of the brakes (£300,000 at current prices). The advantages were a 40-per cent saving in engine running from faster trains, a reduction in requirements for 1,000 to 1,500 locomotives, the creation of additional line capacity by reducing the distance between the slowest and fastest trains, and the saving of 50 accidents a year at £2,000 each or £100,000.[1] The net comes out to a range of plus or minus £1.3 million per year. This figure takes no account of the resulting improvement in freight service or any increase in revenue (or slowing down of the diversion of traffic from rail to road) which might result.[2] Mr. Parkhouse believes that the government would have directed the equipment of freight trains with brakes long ago—' probably before the beginning of this century '—but for the existence of a large fleet of privately-owned wagons.[3]

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[1] See D. E. C. Eversley, 'The Great Western Railway and the Swindon Works in the Great Depression', *University of Birmingham Historical Journal*, Vol. V, No. (1957), p. 177.

[2] H. Cole. *op. cit.*

[3] See A. P. Hunter, 'Freight Rolling Stock', *British Transport Review*, Vol. III, No. 3 (December 1954), pp. 179–201, who claims that fitting brakes to 500,000 cars would be too costly. He would limit brakes to the new large 24½-ton cars, and to main-line cars. In the issue of April 1955 (Vol. III, No. 4), S. E. Parkhouse criticizes this limitation, and comes out in favour of all cars (p. 364). Mr. Hunter offers a rebuttal (*ibid*, pp. 377–78). He suggests that Mr. Parkhouse has over-simplified the problem and neglected the extra costs of shunting in marshalling yards with all the coupling and uncoupling of vacuum hoses entailed. It may be observed that this point which seems absurd to people acquainted with practice elsewhere, may not be in view of the greater amount of shunting per ton mile in Britain than elsewhere because of the shortness of the average train haul.

This is where wholesale destruction would have helped, and the British economy has been worse off, rather than better, with the free gift of the past. Capital investment may be more readily made good in a developed economy than the blocks to technical change from external economies overcome. It is true that the accumulated depreciation of World War I did not bring with the consolidation of private lines an elimination of private wagons. But wholesale destruction might have enabled the country to make a fresh start. And a fresh start was needed. No nation normally has the option of destroying or scrapping existing equipment and starting again, in the same way as a developing country, or one emerging from a destructive war. Private owners clinging to their privileges inhibited the railroads from acting as if the old cars, or freight cars without brakes, had no value. Until they were nationalized, or the coal wagons were, the British railways were handicapped by the fact that they started out in the 1830s with the example of the canals and roads very much in mind, and sought to act as common carriers, on which individual traders were initially expected to provide their rolling stock and their motive power.[1] This early proved unworkable for locomotives, but its unsatisfactory results in rolling stock were recognized too late or change inhibited by the tradition of laissez-faire. Sherrington states that the policy of private ownership of wagons would be tolerated in no other country.[2] A later start, a governmental act of great authority, or wholesale destruction permitting a fresh start was necessary to achieve a more workable basis. In the end it was nationalized.

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[1] S. E. Parkhouse, ' Railway Freight Rolling Stock ', *op. cit.*, pp. 216–18. Mr. Parkhouse points out that 55 per cent of covered stock, 14 per cent of open stock and 80 per cent of cattle stock already have vacuum brakes, and—a truly technological indivisibility—that many of the private wagons are unsuitable for accelerated running, especially those with grease lubrication, instead of oil. For a discussion of lack of standardization in frieght cars, see Ministry of Reconstruction, Advisory Council, *Report on the Standardization of Railway Equipment* (Cd. 9193), 1918, which mentions that there were at that time 200 different types of axle boxes, and forty different types of hand brake.

[2] Jean Cadot, ' L'Analyse marginaliste et le choix des investissements de transport,' paper presented to the Colloque sur l'Application aux Transports des Theories Marginalistes, Nice 29 septembre—1 octobre, 1960, observes that the French railway system divides investments into three categories: those for productivity, which would be justified with fixed traffic; those for enlarging capacity, and those to improve the quality of the service. The first category covers two-thirds of current investments. But of course many investments have elements of all three characteristics.

I cannot forbear from relating the story told me at the University of Birmingham by Dr. D. R. Wightman. Freight trains going down a long hill on the line from Bristol to Birmingham are unable to make it without having their hand (shunting) brakes tight. The train is stopped at the top of the hill. The brakes of each car are adjusted, being struck, on occasion, to assist in the process, by a wooden club resembling a cricket bat. The train descends the hill slowly. At the bottom, the process is reversed and the brakes are released. In all, each train is delayed on the hill for half an hour.

[3] *Loc. cit.*, p. 242.

The same historical issue exists for the steel industry at many points, but nowhere, perhaps, so much as in the question of the location of coking. By-product recovery coke ovens came into use after 1880 when much of British industry was already based on beehive coke ovens located at the collieries.[3] There were considerable economies available from building new coke ovens at the steel mills for brand new plant. What inhibited the steel companies, no one of which was fully integrated by 1900[4] was either Frankel's interrelatedness, Salter's cheap labour and high capital cost, simple economic irrationality which made steel mills incapable of taking advantage of profit opportunities, or lack of vertical integration which made steel firms uncertain about the costs and profits of the beehive ovens, fearful that the price could be lowered if they entered. Later when vertical integration occurred, by-product coke ovens came into general use.[5]

Standardization

A special form of external economy in technology exists in standardization. Where a single firm has several types of equipment for the same job, it pays to scrap the non-standard ones first as Cole found for locomotives and Holland for buses. Odd types acquired in mergers were eliminated ahead of older standardized models to save the additional operating expense from servicing an unnecessarily heterogeneous bus or locomotive park. Replacement with a modern model may be discouraged by the diseconomy in servicing more than one model while the stock of equipment is being turned over at the depreciation rate.

But standardization within the firm may be of minor importance compared to standardization among firms. This is illustrated by the slowness with which the Great Western Railway standardized on a single gauge, with the necessity to transship Midland supplies for the Southwest in Gloucester; in the 200 types of axle boxes and 40 different types of handbrakes, already mentioned. Examples are legion. The different railroads in Britain adopted different automatic brakes for passenger cars, whereas the adoption of a common standard would have lowered capital costs by £400,000,[1] quite apart from the gain in operation efficiency. Parkhouse doubts whether this standardization could have been achieved under company management. The Ministry of Reconstruction blames the companies for failing to adhere to the regulations laid down by the Railway Clearing House for privately-owned cars, and finds the cause in the fact that most railroads built their own rolling stock. Other companies which buy from outside private firms do not suffer this ' riot of individuality '. The railway companies claimed that they built cheaper, but the Ministry doubted that they provided adequately in their costs for rates and taxes, ground rent, and depreciation.[2]

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[1] Sherrington, *op. cit.*, p. 213.

[2] *Ibid.*, p. 214.

[3] G. C. Allen, *British Industries*, London, Longmans, Green, 2nd ed., 1939, p. 93.

[4] T. H. Burnham and G. O. Hoskins, *Iron and Steel in Britain*, 1870–1930, London, Allen & Unwin, 1943, p. 39.

[5] See P. W. S. Andrews and Elizabeth Brunner, *Capital Development in Steel*, Oxford, Blackwell, 1951, p. 146. Just before the big amalgamations of 1929 to 1931, pig iron producers controlled 54 per cent of the coke needs. (Allen, *loc. cit.*, p. 114).

But there is no need to restrict examples to the railroads. I was told during the war, but have been unable to verify it, that there were 200 sizes and designs of manhole covers produced for current use in Britain, with specifications laid down by various local boards and authorities. Plummer notes that in World War I the organization of electricity generation and distribution was found inadequate: with no fewer than 70 generating stations, fifty different systems of supply, twenty-four voltages and ten different frequencies. ' It was the old story of numerous parochial undertakings during the early experimental stages when nobody had vision enough to think in terms of planned development on a national scale.'[3] But surely it is too high a requirement to demand vision on a national scale of private enterprise. The individual firm cannot standardize until some extra-firm unit—the industry, or government,—has adopted the standards. It is sometimes suggested that the electricity companies were obstructed by gas concerns, interested in hobbling them.[4] The alternative view is that Parliament acted too little and too late, without the need for encouragement.[5] As every householder in Britain knows, some of the results of failure to standardize are still in evidence.

The failure to standardize can be regarded as a penalty of the bad start. Latecomers can observe the importance of standardization and take steps to adopt a practical standard.[6] Or it may be regarded as a shortcoming of an intransigent attitude of laissez-faire. Attempts to get governments to impose standards may be rejected,[1] or government standards can be ignored, as in the Gauge Act of 1846, or the standards may not be worked out properly because of the opposition of those affected, as in the case of fitting brakes to freight cars, in Parkhouse's view, or because of incompetence, as possibly in electricity.

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[1] Parkhouse, *op. cit.*, p. 211.

[2] *Op. cit.*, Cole observes that the Great Western Railway undertook to build its own locomotives after the failure of outside builders to meet ' impossible specifications ' laid down by the railroad's chief engineer. These, however, were broad gauge. A worse crime against standardization was for the Great Western later to build standard gauge locomotives at home in small numbers. Eversely gives an interesting account of the running battle between the financiers, concerned to place orders outside the firm—in some cases at the works of directors—and the technocrats determined to control their own designs.

[3] Alfred Plummer, *New British Industries in the Twentieth Century*, London, Pitman, 1937, p. 21.

[4] See J. H. Dunning, ' The Growth of United States Investment in United Kingdom Manufacturing, Industry, 1856–1940,' *Manchester School*, Vol. XIV, No. 3 (September 1956).

[5] Professor W. H. B. Court tells me that he knows of no evidence for active obstructionism by the gas companies.

[6] Jervis seems to protest unduly in dismissing the unimportance of lack of standardization of British canals, on the ground that through traffic is more appropriate to railroads (*op. cit.*, p. 118). Some gifts from the past are better than others, and in other countries, with standardized canal size, there is long-distance barge traffic.

A more familiar type of external economy relevant to technical change, and widely discussed in the development literature, is the provision of technical education by the state. Much has been made of the neglect of British technical education, and its late development.[2] While Jewkes, Sawers and Stillerman[3] are sceptical of all generalizations about inventions, including the one that early inventions were the work of empiricists, while those after 1870 demanded more scientific and technological training, there seems to be little doubt that British universities and public bodies were slow in responding to the widely recognized need for more technological education.[4] I am in no position to evaluate the importance of the lack of technically trained personnel in positions of influence on the adoption of modern technology by British industry. Much of the discussion in the literature deals with invention and innovation, whereas the present interest is limited to the adoption of existing technology, or imitation. But to the extent that numbers of trained personnel are important to imitation, and that some firms are unable to adopt the most modern techniques for lack of appropriate staff to recognize or apply useful methods, the external nature of the economy is familiar. It is stretching Frankel's term perhaps to call this interrelatedness, but separate firms are prevented from adopting profitable techniques for lack of related factors of production.

Monopoly

Examples from railways and electricity raise the question of the effect of monopoly. The usual view is that competition will force a firm to adopt modern standards to survive.[5] Or that much obsolete technology is kept in operation by the unwillingness of labour, with monopoly control, to permit the introduction of labour-saving machinery or of practices, like double shifts, of which labour does not approve.

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[1] It is interesting to observe in 1961, as Pakistan and South Africa have converted to a decimal coinage, and Australia plans such conversion, that the florin was introduced after 1847 as the first step in such a measure, which was to have coins of 1/10 and 1/100 of a pound. The Society of Arts recommended decimal coinage, weights and measures in 1853, but the measure to appoint a committee to investigate the question barely won in the House of Commons, and the move lapsed. See Leone Levi, *The History of British Commerce*, London, Murray, 2nd ed. 1880, p. 474.

[2] See, for example, Stephen E. Cotgrove, *Technical Education and Social Change*, London, Allen & Unwin, 1958.

[3] John Jewkes, Davis Sawers, Richard Stillerman, *The Sources of Invention*, London, Macmillan, 1958.

[4] C. F. Carter and B. R. Williams, *Industry and Technical Progress*, London, Oxford University Press, 1957, p. 100. Cotgrove (*op. cit.*, p. 27) believes that the need was not widely recognized, despite the Royal Commission on Technical Instruction of 1882, and stresses the complacency of the Royal Commission on the Depression of Trade and Industry, in 1885, and the neglect of science and apathy toward technical instruction bred by 50 years of industrial pre-eminence.

[5] D. L. Burn, *Economic History of Steel Making*, Cambridge, Cambridge University Press, 1940, regards imperfections of competition, along with the structure of the British capital market, as the chief obstacles to the emergence of new high capacity plant in steel in Britain (p. 263).

Several points may be made. In the first place, railroading was much more competitive up to 1914 than one would normally think, as railroads fought each other for passenger traffic on competing routes and to competing holiday resorts. Since World War I, moreover, the railroads have met increasing competition from road haulage. Competition has punished uneconomic behaviour in the British railroads.[1]

Secondly, it may be true that factor monopoly slows down the rate of application of technological progress, by limiting access to capital on the part of small firms, or through labour forbidding the introduction of new machinery. Allen suggests that worker opposition to double shifts slowed down mechanical improvement in the cotton textile industry in Lancashire.[2] Labour objection or unavailability of capital, it should be noted, increase the incentive for improved technology at the same time that they make its realization more difficult. But Carter and Williams found few firms frustrated by a lack of finance,[3] or hindered by labour unions.[4] They suggest that when finance is cited as an excuse, it is likely that a family firm is unwilling to give up control; and that bad labour relations, hampering the general life of a firm, may focus on technological change, even when they do not originate in the issue.

Third, as in factor markets, so in the market for output, monopoly cuts both ways: it restricts the output of the industry, but increases the incentive for outsiders to break in. Unless entry is effectively limited, by the requirement of large amounts of capital, or vital patent control, entry in the long run will take place.

But the major consideration is that the fact of monopoly is less important for technical advance than its nature. Where the monopolist or monopolistic competitors are calculating and maximizing, technical progress will take place. There will be investment in research and in development, which are generally found to yield high returns. Higher prices will make old equipment longer able to cover variable costs in the short run; and low-cost producers will expand less in the short run if they take account of the elasticity of demand facing them than if they consider it infinite. But in the longer run, if all participants in the market calculate and maximize, innovations will come forward, imitation will take place. On Frankel's model, old equipment will be replaced by new, when no change in scale is involved, and relative factor prices favour it, through the ratio of fixed to variable costs which emerges from the fixed costs of the two processes—assuming away interrelatedness. Under Salter's formulation, depreciation will reduce output, raise price and produce superprofits for the low-cost producer, which will be driven down to normal monopoly profits by new capacity to replace that worn out. Or technological innovations will afford an opportunity to expand output and increase profit, despite some lowering of price, which will strand old equipment, remove it from the market, and allow still more room for modern technology, provided that factor prices are right.

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[1] Perhaps more the bad pricing policies than the technological obsolescence. See C. F. Carter and B. R. Williams, *Science in Industry*, London, Oxford University Press, 1959, p. 71; and especially C. I. Savage, *An Economic History of Transport, op. cit.*, pp. 106, 142. Required to charge a uniform mileage freight rate, the railroads found themselves losing to trucking the profitable long-haul business, and left with the costly, short hauls, the exact opposite of what a rational allocation of tasks would have produced.

[2] G. C. Allen, *British Industries, op. cit.*, p. 247.

[3] C. F. Carter and B. R. Williams, *Investment in Innovation*, Oxford University Press, 1958, p. 83.

[4] Carter and Williams, *Industry and Technical Progress, op. cit.*, pp. 172–73.

On the other hand, the monopoly may be static, the result of monopolistic behaviour, holding prices up and production down, whether by a single firm, a handful of firms, or many which refuse to compete either in price or quality or in any form of change. This is non-maximizing or uneconomic behaviour, which we are about to discuss. It is also monopoly. But it is better to blame the lack of technical progress on the non-economic behaviour than its market symptom. Carter and Williams rightly say that competition has two effects: it keeps an industry on its toes, and prevents the emergence of the static monopoly; but it also inhibits planning in the dynamic one.[1]

Non-Economic Behaviour

Apart from technological interrelatedness, and the inability to share the uncertain benefits of technological change involving investment by more than one firm, much failure to stay abreast of technological progress is attributable to non-economic behaviour, or attention to the wrong variable from the point of view of the economy.

One such variable is the life of ease—'Britain's too easy contentment', as Marshall called it,[2] or the comfortable standard of life which could be earned in the tinplate trade with a modest sum, to quote Minchenton on an industry which was peculiarly stagnant.[3] This is sometimes characterized as conservatism or timidity in the face of change. But it is perhaps more accurate as well as more charitable to regard it as maximizing comfort in the short run. Cole points out that this behaviour may apply not only to the firm, but to departments within it. When Tyrrell was the Superintendent of the Great Western Railway from 1864 to 1888, he slowed down trains, rather than sped them up; the operating department in these years refrained from asking the chief mechanical engineer for new and faster designs, and the latter refrained from offering it any.[1]

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[1] *Ibid.*, p. 163. See also *Investment in Innovation, loc. cit.*, p. 142 which lists both more and less competition as influences stimulating technological innovation.

[2] Alfred Marshall, *Industry and Trade*, London, Macmillan, 1920, p. 102.

[3] W. E. Minchenton, *op. cit.*, pp. 105–7. P. Sargant Florence, *The Logic of British and American Industry*, London, Routledge and Kegan Paul, 1953, p. 304, suggests that the gross standard income a British business man needed was £4,000 to £5,000, but that beyond that sum, conventional needs were satisfied and the demand for income in terms of effort, became unitary-elastic at higher prices.

But a firm may not maximize profits because it is interested in some other variable—a quite life free from public hounding, or maximizing its life's span. Andrews and Brunner defend the United Steel Company's investment policies from the criticisms of Burn,[2] and of Burnham and Hoskins[3] in a variety of ways, but they do not claim that it made the largest possible amount of money over time.[4] The justification for a horizontal combine with plants in several locations, of course, is that in making as large a profit as possible it will improve economic efficiency by expanding in the low-cost locations and cutting back in the high. The South Midland plants at Appleby-Frodingham were profitable throughout the 1920s and 1930s,[5] but were not expanded until 1938, and after World War II. The contrast is with the Templeborough works which was enlarged by bank loans, and especially with Workington. Capital investment in the latter was undertaken in the 1920s, despite the unprofitability of the plant and its high cost, because the company was ' very conscious of its responsibility as an important employer of labour in one of the depressed areas with which public opinion was very concerned '.[6] The company's 'faith in Workington'[7] was finally justified to the extent that it produced profits in the armament boom of the late 1930s, but these were lower than other subsidiaries on an invested-funds basis.

There will of course be occasions when investment is called for in the low-profit units of a firm, rather than to expand the profitable units and snuff out the losers. If there is an assurance or a reasonable hope that the laggard can be brought up to the normal rate for the firm, attention to it is justified. In general, this will require some change in operating method. What cannot be regarded as economic, however, is the ' sharing out ' of replacement or net investment funds, regardless of prospective profit rates.

Another form of uneconomic behaviour is to maximize a technical rather than an economic variable. Government may require it. In the 1880s, the Board of Trade reacted against high accident rates by raising safety standards and the need for investment. Heavier passenger cars, in particular, contributed to the need for more powerful and heavier locomotives. But neither safety nor cost were permitted to inhibit the interest of railway engineers in racing. The average speed on four principal runs of the Great Western from London to Plymouth, Cardiff, Bristol and Birmingham went from 36–48 miles per hour in 1888, to 47–53½ in 1900, and to 51–59 in 1912.[1] Racing called for new locomotive designs, but also for investment in the permanent way, for tunnels, bridges, straightening curves, and so on. These investments could be loosely justified in terms of attracting passenger traffic, for the public was interested in speed almost as much as the engineers. It and the growth of the level of living raised railroad revenues at the end of the pre-war period. But there was a strong technocratic bias, too. The romance of railroading then led to investment on purely technical grounds, just as the romance of railroad is said now to give railroad engineers a vested interest in obsolesence.[2]

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[1] *Op. cit.*, p. 30. Carter and Williams state (*Investment in Innovation*, *op. cit.*, p. 48) that craft firm managers are unwilling to innovate or to hire highly paid functional specialists for fear of upsetting old department managers who came up the hard way. This may reflect a desire for a quiet life, or possible a sense of public responsibility, about to be discussed. Or it could be an ' economic irrationality ', comparable to the attention to the physical rather than the economic life of a machine, which prevents the manager from discharging (buying up the contract of?) obsolete employees because they are under retirement age.

[2] See especially Duncan Burn, ' Steel ' in Duncan Burn, ed., *The Structure of British Industry*, Cambridge, Cambridge University Press, 1958, Vol. I, p. 287: ' In a sense, this combine (the United Steel Company) was the antithesis of both the popular principles of rationalization, regional and product specialization.'

[3] *Op. cit.*, pp. 45, 120, 155, 180, etc.

[4] Andrews and Brunner, *op. cit.*, *passim.*

[5] See quotations from the chairman's annual reports, which say consistently from 1923 to 1928, and again in 1930, that Appleby-Frodingham was working at high capacity and profitably (*ibid.*, pp. 128, 129, 130, 154). See also the table for 1930s, pp. 204, 5.

[6] *Ibid.*, p. 208.

[7] *Ibid.*, p. 362.

More widespread economic irrationalities, however, stem from an understandable desire to find rules of thumb to replace calculation of costs and revenues. One ubiquitous practice is to retain all equipment with a useful physical life. Holland notes that despite technological change buses were normally scrapped by the Bristol company between the end of their accounting life and the physical wearing out of the bus-body. It took permission of the accountants to write-off a bus ' with money on its back ', i.e. which had not been fully depreciated. Such write-offs required exceptional justification, and were a mark of failure; ' depreciation-free running ', on the other hand, bespoke success.[3]

The rule that bygones are bygones is difficult to apply, and it is hard to ignore the physical durability of obsolete plant in decisions on scrapping.[4] Minchenton mentions with awe the United States Steel write-off of $270 millions of old-type tinplate works, after building a strip mill, and remarks that ' no such readiness to scrap old plant was abroad in South Wales '.[5] The British accounting team studying American productivity after World War II singles out as remarkable the scrapping of a plant ' with years of useful life still left ' because the management was convinced the product had no future.[6] P. L. Cook mentions that Pilkingtons suffers in plate glass from the fact that it does not require a new machine and modern machines tend to be more economical.[7]

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[1] Cole, *op. cit.*

[2] A. J. Pearson, *op. cit.*, p. 34.

[3] David Holland, ' The Replacement of Buses in Bristol ', to be published in a later issue of The Bulletin.

[4] When there is little maintenance cost, site value or second-hand or scrap value, capacity is sometimes maintained for stand-by operations, rather than scrapped. With a static technology and constant factor prices, this will inhibit new investment, since variable costs on the old technique set a ceiling to output price. Durability thus has its effects.

[5] Minchenton, *op. cit.*, p. 196 note.

[6] Anglo-American Council on Productivity, *Productivity Report on Management Accounting*, London, November 1950, p. 7, para. 13.

[7] P. Lesley Cook, ' The Flat-Glass Industry ' in P. Lesley Cook, ed., *Effects of Mergers*, London, Allen & Unwin, 1958, p. 305.

A second irrationality is to link replacement and net investment to current, rather than to future operation. In replacement decisions this practice is readily understood, based on the tacit assumption that tomorrow will be the same as today, and the need to minimize decision-making.

Less justifiable is to gear today's net investment to today's profits. Two possible rationalizations can be made: one, that tomorrow will be the same as today, as in the case of replacement, plus constant or decreasing costs and sufficiently elastic demand; the other is that the firm's access to capital may be limited, and it can invest only when it has depreciation allowances or profits available. In general, however, net investment should depend upon the prospect of profit, not the availability of cash. Andrews and Brunner cite limitations of cash as the reason for low investment by United Steel Company in the 1920s and early 1930s, and low current profitability.[1] In terms of prospective profits, the Appleby-Frodingham works should have been expanded in the 1930s; that it was not done is explained in part by the fear of interfering with its profitable operation.[2]

Third, while it is important not to be misled by them, some accounting rules are called for. But these rules can mislead and distort. ' It is an axiom of good accounting that capital expenditure should be capitalized and that only revenue expenditure should be debited against current account, but there used to be a tendency for English companies to make capital expenditure out of revenue and vice-versa '.[3] After the revision of railway accounting procedures in 1928, the use of depreciation to built a fund, rather than to write down capital, strengthened the hands of the railway engineer who wanted to spend up to a certain amount, but weakened him when he wanted to spend more.[4] It further had the uneconomic effect of freezing the distribution of renewal investment by departments.

It is possible to be more iconoclastic and to believe that accountants have perpetuated a ' myth ' of fixed assets, which are written off slowly, as opposed to the rapid write-offs of other expenditure of a similar sort which yields its return over a long period of time, e.g. advertising and research and development. But there is no escape from rules, despite the difficulty in making fine distinctions. The greater uncertainty as to the productivity of these latter ' investments ' may warrant charging them to revenue, but not expenditure on fixed assets, exceptional circumstances aside.

One final point: analytically, technical advance could be blocked by vertical integration and internal diseconomies, rather than by vertical disintegration and external economies: For example, it might have happened that the railroads clung to the small freight car because they were concerned not to destroy the value of their existing rolling stock, traction, or right of way. But this analytical possibility seems to me to lack historical support. The system was relatively disintegrated, and the market system failed to take advantage of economies which were, or might have proved to be, external to the firm.

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[1] Andrews and Brunner, *op. cit.*, pp. 144, 349.

[2] *Ibid.*, p. 209. This is rather reminiscent of the Arkansas fiddler who couldn't repair his roof in the rain, and didn't need to when it stopped. The loss of profits from current operations is of course an added cost of investment. It was incurred at Appleby-Frodingham in 1938–39.

[3] C. Douglas Campbell, *British Railways in Boom and Depression*, London, P.S. King, 1932, p. 36. The reference seems to be to railway companies.

[4] Cole, *op. cit.*

Conclusion

This investigation suggests the desirability of modifying Frankel's view of interrelatedness, or perhaps merely making it explicit, by insisting upon the external nature of some of the economies involved in technical change; and Salter's model to allow both for external economies and for economic irrationality. It hardly constitutes a plea for vertical integration and socialism, since integrated firms and governments, on occasion, show themselves to be economically irrational.[1] But it seems to me worth historical exploration to ascertain whether the disability of a highly articulated system of small, independent firms, linked through a complex system of merchants and markets, is, for all its efficiency in production in a given state of the arts, less effective in responding to innovation elsewhere than vertically integrated firms.[2] This is not the place to explore the merits and drawbacks of the merchant system, which has attracted attacks and support from students of British industry.[3] It may nonetheless be a factor in reducing technical change, as opposed to direct selling, with its pressure of the customer on the producer to meet new needs, and of producer on customer to accept new goods.

To the extent that any positive conclusion emerges, it is the familiar one, that routine and institutionalized procedures should favour calculation, rather than opposition to change, or change for change's sake. Of these last two there was more of the former than the latter in British economic history: the response to suggestions, ' Has any other fool tried it yet? '[4] or ' Teach your grandmother to suck eggs; we tried that 50 years ago '.[5] Decision-making has a cost; but the returns to it are typically high.

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[1] See above, the discussion of the railroads building their own rolling stock and locomotives.

[2] Few economists find anything good to say about vertical integration, See, in particular, Jewkes, ' Is British Industry Inefficient? ' *op. cit.* ' The advantages of integration in industry are normally very limited.' (p. 10) and his statement that vertical integration can lead to a false sense of balance (p. 8).

[3] For the attacks, see *e.g.* Allen, *op. cit.*, pp. 18–19, 311; Burnham and Hoskins, *op. cit.*, pp. 210–11; M. E. Beeseley and G. W. Throup on ' The Machine-Tool Industry '. In Duncan Burn, ed., *The Structure of British Industry, op. cit.*, Vol. I, pp. 380 ff. In defense, see A. Marshall, *Industry and Trade*, pp. 616–18.

[4] Minchenton, *op. cit.*, p. 195.

[5] Burn, *Economic History of Steel Making, op. cit.*, 296.

A REPLY TO GLASSBOROW'S CRITICISM OF THE ECONOMIC ASSESSMENT OF THE LONDON-BIRMINGHAM MOTORWAY

By R. F. F. Dawson

In the November issue of The Bulletin Glassborow [5] discussed the economic assessment of the London-Birmingham motorway made by Reynolds of the Road Research Laboratory and Beesley of the University of Birmingham [1]. Beesley's reply [2] was published in the May issue which also contained a brief rejoinder from Glassborow [6]. Reynolds has now left the Laboratory and I have taken over his work. I think before the matter is closed I should comment on Glassborow's original article.

1. *Social and commercial returns*

Glassborow's main criticism is that the method of assessment used in the motorway study, which he refers to as a social return, is put forward as if it were the same thing as a commercial rate of return. The differences between various methods of assessing the return from investments are examined in considerable detail by Foster [4], in the article which followed Glassborow's, and it is not necessary therefore to discuss them at any length in this paper.

The return from a road improvement cannot be assessed on ordinary commercial principles as the use of the road is not usually sold to the vehicles that travel on it but is made freely available. (It is of no significance if the authority which builds the road is also the one that collects the fuel tax.) On the other hand, unlike some purely welfare investment, such as the building of schools, road improvements may yield direct monetary benefits to the users. What was attempted in the motorway study was to measure all factors affecting the road user which could be brought within ' the measuring rod of money '; in fact to measure the consumers' surplus. This is not the same as a social surplus but it is not possible to say whether it is greater or smaller as it is not known whether the net effect on non-road users is a gain or a loss.

Perhaps Road Research Technical Paper No. 46 should have pointed out that the assessment was not equivalent to a commercial rate of return; though this does not imply that the exercise was not well worth doing nor that the investment in the motorway will not yield a useful return.

The answer to Glassborow's point that the investments are sometimes rejected even if the commercial rate is more than twice the rate of interest, is surely that it is largely a question of the risk involved and of the availability of capital.

The conclusions to be drawn from this discussion are:

(i) The results of two or more investments are only comparable if the rates of return are calculated on the same basis.

(ii) In the case of investments in roads the rate of return should continue to be calculated as at present. (This does not imply that no improvements can be made in the methods used to calculate the return.)

2. *The road system at present is not being used efficiently*

Mr. Glassborow contends that one cannot say that the benefits due to road improvements are economically justifiable unless the ' taxation system ensures that the road system is being used efficiently ' and goes on to say that a net benefit should not be calculated as the difference between the positions before and after a road improvement if the positions are not optima. This argument seems to be a complete *non-sequitur*. If the situations before and after the improvement are not optimum from the point of the economic use of road capacity, then the resulting benefit may not be the optimum benefit, but the net effect (as long as it is positive) is undoubtedly a benefit.

The economic assessment did not attempt to find the optimum benefit to be derived from a combination of fiscal, economic, geographical and engineering factors but aimed at measuring the effect of building a particular road; one of the factors that was taken as given was the present taxation system. (This does not imply, as Glassborow alleges, any particular belief about the relation between the amount collected in taxes and the economic cost of providing roads nor as to whether the present choice made by road users does or does not bring about the optimum use of roads.) If a different taxation system led to a more economic use of the road system then a different result would probably have been obtained, but it was not the object of the study to find this out.

3. *Valuation of time savings*

I agree with Glassborow that this is a subject on which more research is needed but I do not accept his contention that time savings in the economic assessment of the London-Birmingham motorway were greatly over-valued. His case seems mainly to depend on his hypothesis that ' wages are payment for both time and effort, leisure time should (therefore) be valued at less than hourly wages after tax, the reward for both time and effort '. Time *per se*, however, has no value; it only has a value in relation to the activities which take place in it (practically all of which, other than sleep, require some effort.) The dichotomy that Glassborow sets up between time and effort is in this sense a false one.

In the case of transport workers if the time saved is used for additional work then the employer is getting more passenger-miles or ton-miles for the same wage, since drivers are paid per hour and not per mile; if the time saved is used for extra leisure then the employer is paying less money for the same amount of work. In either case the gain is measured by the wage.

There is no justification for Glassborow's apparent assumption that all time saved by those travelling on business is devoted to leisure; it seems more likely that at least part of the time saved will be devoted to extra work. For those paid by time, even if time-saving results in more leisure, the gain to the employer is the wage earned in the time saved on the journey.

The difficulty of arriving at a value of leisure time was stressed in the Technical Paper, which used a range of values of four shillings to eight shillings per hour; Glassborow says that ' there are good reasons to doubt whether such high figures are justified ', though he does not cite any of the reasons. Very little experimental work has been done on this subject but American results (e.g. Claffey [3]) indicate that the top of this range is by no means too high.

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REFERENCES

[1] Beesley, M. E., and Reynolds, D. J. ' The London-Birmingham motorway. Part II. Economic assessment '. *Department of Scientific and Industrial Research, Road Research Technical Paper No.* 46. London, 1960 (H.M. Stationery Office).

[2] Beesley, M. E. ' Mr. Glassborow on investment criteria '. *Bulletin Ox. Univ. Inst. Stat.* Vol. 23, No. 2, May 1961.

[3] Claffey, P. J. ' Characteristics of passenger car travel on toll roads and comparable free roads for highway user benefit studies '. *Highway Research Board*, 40th Annual Meeting, January 1961.

[4] Foster, C. P., ' Surplus criteria for investment . *Bulletin Ox. Univ. Inst. Stat.* Vol. 22, No. 4, November 1960.

[5] Glassborow, D. W., ' The Road Research Laboratory's investment criterion examined '. *Bulletin Ox. Univ. Inst. Stat.* Vol. 22, No. 4, November 1960.

[6] Glassborow, D. W., 'A Rejoinder', *Bulletin Ox. Univ. Inst. Stat.* Vol. 23, No. 2, May 1961.

A COMMENT ON MR. DAWSON'S REPLY

By D. G. Glassborow

1. *Social and commercial returns*

(a) It is a notable step forward that the Road Research Laboratory now admits that the rate of return calculated in the London-Birmingham Motorway study is not, contrary to what was so clearly implied in that study, properly to be compared with a commercial rate of return.

(b) If Mr. Dawson wishes to draw attention to the fact that a social return takes account of losses to non-road users—the gains to non-road users are those of suppliers and customers of the road users to whom a share of the consumers' surplus is passed on—and would thus be less than the return calculated by the Road Research Laboratory method, I find it difficult to disagree with him. I am also quite prepared to use his and Dr. Beesley's terminology.

(c) If Mr. Dawson wants to discuss risk and availability of capital I would only suggest that the conclusion of such an argument is not really in his favour. As ' Road Research 1960 ' and the final cost figures for the motorway reveal, the forecast rate of return at mid 1960 levels was based on an over-estimate of some 40 per cent in the average vehicle flow and an under-estimate of about one quarter in its capital cost.

(d) I am glad to find Mr. Dawson in his conclusions so close to agreeing with the final paragraph of my original article.

2. *The road system at present is not being used efficiently*

(a) By inadvertently mis-stating the position I have taken, Mr. Dawson finds himself able to regard my argument as a non-sequitur.

(b) I do not wish to allege that he holds any beliefs about road taxes and the economic costs of providing roads. I simply pointed out that the uses of the assessment made by the Laboratory were limited because, as Mr. Dawson confirms, it did not take account of the need for improvement in the system of road taxation. He appears to agree and I do not see the purpose of his remarks on this point.

3. *Valuation of time savings*

Since Mr. Dawson does no more than re-state the argument I criticised, there does not seem much need to answer his remarks, except to say that the definiteness of some of his assertions contrasts oddly with his opening phrase. However, as an aside, may I ask now he converts dollars (Claffey) to shillings? Does he take account of higher output per manhour in America as, to be consistent, he should?